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Groundfish Stock Assessments for the West Coast of Canada in 1990 and Recommended Yield Options for 1991

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Nanaimo, British Columbia V9R 5K6

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by

J. Fargo and B. M. Leaman

(Editors)

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ABSTRACT

Fargo, J. and B. M. Leaman. (ed.). 1991. Groundfish stock assessments for the west coast of Canada in 1990 and recommended yield options for 1991. Can. Tech. Rep. Fish. Aquat. Sci. 1778: 320 p.

Groundfish stock assessments for the Pacific coast of Canada, for 1990, and yield options, for 1991, are presented in this document. Assessments have been conducted for the following species: lingcod, Pacific cod, petrale sole, Dover sole, rock sole, English sole, sablefish, Pacific hake, spiny dogfish, walleye pollock, Pacific ocean perch, yellowmouth rockfish, rougheye rockfish, redstripe rockfish, silvergray rockfish, yellowtail rockfish, canary rockfish, quillback rockfish, copper rockfish, and hagfish. A number of analytical methods have been employed in these assessments, e.g., surplus production analysis, virtual population analysis, and dynamic pool models. Biological factors are the only consideration for these assessments and yield options. Yield options are recommendations to the fishery managers of the Offshore Division of the Fisheries Branch on catch limitations and other management procedures. Alternative options allow the managers to consider high risk and low risk yields in relation to a stock's potential productivity.

Key words: groundfish stock assessments, yield options

RÉSUMÉ

Fargo, J. and B. M. Leaman. (ed.). 1991. Groundfish stock assessments for the west coast of Canada in 1990 and recommended yield options for 1991. Can. Tech. Rep. Fish. Aquat. Sci. 1778: 320 p.

Le présent article présente des évaluations des stocks de poissons de fond de la côte pacifique canadienne pour 1990 de même que des options d'exploitation pour 1991. Les évaluations ont porté sur les espèces suivantes: morue-lingue, morue du Pacifique, plie de Californie, sole à petite bouche, sole du Pacifique, sole anglaise, morue charbonnière, merlu du Pacifique, aiguillat commun, goberge de l'Alaska, sébastes à longue mâchoire, à bouche jaune, à oeil épineux, à raie rouge, argenté, à queue jaune, canari, à dos épineux et cuivré, et myxine. L'analyse de la production excédentaire et des populations virtuelles de même que l'utilisation de modèles de bassins dynamiques sont au nombre des méthodes qui ont été utilisées. Seuls les facteurs biologiques ont été pris en considération dans l'établissement de ces évaluations et de ces options d'exploitation. Cer dernières sont des recommandations pour les gestionnaires de la Division hauturière, Direction des pêches, touchant la limitation du volume des prises et autres activités de gestion. Les différentes options présentées aux gestionnaires leur permettent de juger des risques liés aux différents taux d'exploitation possibles au regard de la productivité potentielle des stocks.

Mots clés: évaluations des stocks de poisson de fond, options d'exploitation

1.0 EXECUTIVE SUMMARY

1.1 INTRODUCTION

This document contains brief summaries of stock conditions of the important groundfish stocks, and recommendations for their management to the Offshore Division of the Field Services Branch. The report is based on the more extensive report prepared by the staff of the Groundfish Section of the Fisheries Research Branch, located at the Pacific Biological Station, Nanaimo, British Columbia, Canada V9R 5K6.

Department biologists begin their assessments in the spring of the year using a multi-year data base for fishery statistics and biological research. A variety of assessment models are used including several catch-at-age sequential analysis models, age-independent surplus production models, yield-per-recruit, and linear models. Assessments are completed in August after review by a committee of DFO Groundfish scientists. Review may also incorporate outside investigators (government or non-government), where desired by the DFO Research Branch. Assessments are then reviewed by the DFO Pacific Stock Assessment Review Committee and recommended yield options are collated and sent to the Offshore Division of Fisheries Branch for consideration.

1.2 LIST OF ASSESSMENTS

The following assessment texts are presented as chapters in this stock assessment document.

Lingcod--L. J. Richards and C. M. Hand
Pacific cod--R. P. Foucher and A. V. Tyler
Flatfish--J. Fargo
Sablefish--M. W. Saunders and G. A. McFarlane
Pacific hake--M. W. Saunders, L. J. Richards, A. V. Tyler
Dogfish--B. L. Thomson, M. W. Saunders and M. S. Smith
Walleye pollock--G. D. Workman and M. W. Saunders
Slope rockfish--L. J. Richards
Shelf rockfish--R. D. Stanley
Inshore rockfish--C. M. Hand and L. J. Richards
Pacific hagfish--C. M. Neville and R. J. Beamish

1.3 GENERAL CONDITION OF THE STOCKS

Views on current condition of groundfish species/species groups on the west coast of Canada are summarized in the table below. Since yield options are developed for 51 different stocks, only a general concept of species condition can be portrayed in this summary. A somewhat more complete account is given in Sections 1.4 and 1.5 of this Executive Summary. A table of recommended catch levels and management options is given in Section 1.7. The full reports follow as separate chapters.

Species or species group	Current stock condition
Strait of Georgia lingcod	Low
Offshore lingcod	Average
Pacific cod	Average
Petrale sole, Rock sole, English sole, Dover sole, and Arrowtooth flounder	Low to high*
Sablefish	Above average
Pacific hake	Average to high*
Spiny dogfish	Average to high*
Walleye pollock	Low to average*
Slope rockfish	Low to average*
Shelf rockfish	Average
Inshore rockfish	Low to average*

* depending on specific stock.

1.4 MAJOR FISHERY CONCERNS

Groundfish research staff have met, over the past four years, with the industry's Deep Sea Trawlers Association (DSTA) to try to develop a joint DFO-DSTA rockfish survey. The minimum objective is to form a relative abundance trend series that both industry and fisheries staff will believe. The procedures that are jointly agreeable are now in place. Joint surveys between the Deep Sea Trawlers Association and Groundfish Section Staff have been postponed until funding mechanisms are worked out.

For inshore areas, rockfish species (quillback, copper, yelloweye rockfish) are being taken in some locations of the Queen Charlotte Strait, Johnstone Strait, and Strait of Georgia at rates greater than can be supported by natural production.

Strait of Georgia lingcod have been over-exploited in the past and continue to be. There is evidence that the initial depletion of lingcod was due to the commercial fishery, but that the sports fishery now accounts for most of the present take, and must be controlled if rehabilitation is to ensue.

With the adoption of a coastwide management plan for Pacific ocean perch, the biologists and managers agreed to make special provisions for the Goose Island Gully stock in Queen Charlotte Sound, since this stock is below the standing biomass level that would produce maximum yield. Yet the stock is being fished at levels that are not sustainable due to quota over-runs. Biologists are concerned about the quota overruns that have occurred annually in all statistical areas except Moresby Gully, and believe that the Pacific ocean perch resource is being eroded. The quota overruns extend to westcoast Vancouver Island, canary and silvergray rockfish and yellowmouth rockfish in Queen Charlotte Sound. The persistent quota overruns will soon cause a decrease in yield potential in these stocks (See Appendix Table 3).

An additional problem which hampers effective stock management is a lack of formal objectives from a stock perspective and the stock complex as a whole. This results in confusion as to the appropriate management protocols which need to be adopted when dealing with the mixed-species nature of the groundfish fishery, and the often opposing results of alternative actions. More effort is required in the development of stock-by-stock objectives and integration of these objectives into an overall groundfish stock management plan. The long-term economic tradeoffs of fisheries on short-lived, highly dynamic vs. long-lived, stable species require analysis. The biological assessments produced by this Branch will form only one part of such an analysis. We are increasingly concerned that the biological and economic penalties arising from the lack of a more integrated stock oriented management plan may be large, and result in overall decreases in stock yields. By highlighting these concerns we hope to stimulate the process of developing an improved system.

1.5 TEXT SUMMARIES OF ASSESSMENTS

Lingcod

Lingcod stocks were assessed with a size-structured model and by historical trends in CPUE. In addition, a new analysis indicated that size at 50% maturity is near 65 cm for female lingcod, well above the commercial size limit of 58 cm. It is recommended that the size limit be applied coast-wide for both sport and commercial species. Stocks were determined to be at extremely low levels in the Strait of Georgia portion of the Vancouver Area and a complete closure to all gear types was recommended. In the remainder of the Charlotte-Vancouver Region, stocks were determined to be at moderate-high levels, with yields ranging from 2700-4600 t in 1990.

Pacific cod

The very strong 1985 year class of Pacific cod is passing out of the fishery, leading to a general decline in abundance from previously high levels. CPUE figures suggest that stocks are now at about average levels of abundance in Hecate Strait (459 kg/h in 1989 and 397 kg/h for the second quarter of 1990). They are lower than average in Queen Charlotte Sound (97 kg/h in 1989) and in the Strait of Georgia (265 kg/h in 1989). The age-structured model developed last year for use with Hecate Strait stocks predicts a potential yield for 1990 of 3248 t and for 1991 of 2777 t. Indications from observer samples and discards from the commercial fishery are that there is a strong 1989 year class developing which will start contributing to the fishery early in 1991. No catch limitations have been suggested for Pacific cod stocks in 1991 because of the projected strong recruitment and continued moderate fishing effort directed at them.

Flatfish

Flatfish stocks were assessed in 1990 on the basis of surplus production analysis of standardized landing statistics, trends in CPUE, yield per recruit analysis, and a length-based simulation model. Petrale sole stocks were determined to be at low levels, rock sole stocks at average to high levels, and English sole and Dover sole stocks at low to high levels. Landing statistics for all rock sole stocks were standardized using a multiplicative model accounting for effects of vessel horsepower on CPUE. Recruitment of the strong 1985 rock sole year-class continued in 1989 for stocks in all Areas except Area 5C. Sustainable yield estimates for rock sole stocks in all Areas except 5C have increased over last year. In Area 5C, estimates of the sustainable level have decreased because the 1985 year-class does not appear to be as strong as it is in other areas. A recruitment increase was also observed for Hecate Strait. English sole in 1989 and yields up to 1000 t may be sustainable in 1991. Area 3CD Dover sole were determined to be overexploited based on estimates of fishing mortality from a new length simulation model. Estimates of sustainable yield have been lowered accordingly. The upper limit of sustainable yield for Area 5CDE Dover sole has been increased by 25% from last year based on estimates of fishing mortality for the stock using a new length simulation model.

Sablefish

Coastwide standardized CPUE values increased from 21.2 kg/trap in 1988 to 22.6 kg/trap in 1989. Biological studies indicate that the change in age frequencies in the fishery may be an artifact of changing effort patterns. Overall the condition of the sablefish stock in the Charlotte-Vancouver area is good. An age-structured forward simulation model was used to project biomass and yield, incorporating numbers-at-age from Virtual Population Analysis (VPA) as the starting vector for the population. Yields ranging from 2,900 to 5,000 t were presented as low to high risk sustainable yield options for 1991.

Pacific hake

In the Strait of Georgia portion of the Vancouver area, a general forward simulation model adapted for Pacific hake was used to project spawner biomass and yield at varying levels of recruitment. The model, using results from a Virtual Population Analysis (VPA), indicated that yields from 8000 t to 14,000 t are sustainable. The offshore stock was assessed on the basis of a stock synthesis model which is a separable catch-at-age analysis that is tuned to survey estimates of biomass and age composition. Coastwide, the biomass of hake decreased from 2142.324 thousand t in 1986 to 1636.780 t in 1989. In the Canadian zone, the biomass increased from 15.414 thousand t in 1986 to 22.756 thousand t in 1989. Sustainable yield estimates from the stock synthesis model ranged from 175 thousand t to 311 thousand t.

Dogfish

The stock assessment for spiny dogfish in both offshore and Strait of Georgia waters remains unchanged from last year. Current harvest rates are below the level of low risk for a sustainable fishery for both areas. As such, the estimated biomasses of 380,000 tonnes (offshore) and 60,000 tonnes (Strait of Georgia) are expected to increase.

Walleye pollock

The 1989 pollock catch in the Canadian domestic fishery decreased from 1112 t in 1988 to 509 t in 1988. The 1988 incidental joint-venture and foreign catch decreased to 907 t from 252 t in 1988. The Strait of Georgia in 1988, using swept-volume trawl and hydroacoustic techniques. Biomass was estimated to be between 9,069 and 22,500 t. Yields up to 5400 t are considered sustainable.

Slope rockfish

Condition and yield potential of slope rockfishes (Sebastes alutus, S. reedi, S. aleutianus, and S. proriger) were assessed with methods including sequential age-structured, length-frequency simulation and stochastic recruitment models. In addition, some stocks were assessed solely on the basis of trends in fishery statistics or biological characteristics, due to data limitations. Stocks of Pacific ocean perch (S. alutus) were generally depressed and have shown no recovery from lowered abundances caused by high fishing mortalities applied during the mid-1960s. Coastwide yield estimates range from 3350-5470 t. Yellowmouth (S. reedi), rougheye (S. aleutianus) and redstripe (S. proriger) rockfishes were in moderate to poor condition with coastwide yield estimates of 1160-2450 t, 250-400 t, and 1450-3270 t, respectively. Redstripe rockfish was not subject to a management control program. Quota recommendations are unchanged.

Shelf rockfish

Stock assessments are presented for seven offshore shelf rockfish fisheries. Quota recommendations are unchanged for the southern and central coast fisheries for canary rockfish. They remain 400-600 and 350-500 t respectively. Recommendations for the southern and northern (Hecate Strait) silvergray rockfish are also unchanged at 400-600. The recommendation for the central coast (Queen Charlotte Sound) fishery for silvergray rockfish is lowered from 700-850 to 200-700. The wide range is a result of recently aged material which indicates significant overfishing in contrast with historical catch rates which are reasonably stable after a sustained harvest of approximately 700 t/yr for over 20 years.

The yield recommendation for the yellowtail rockfish stock of Queen Charlotte Sound is down slightly from last year's range of 1400-3600 to 1400-3000. The change is a result of changes in the method of analysis. We continue to recommend an experimental yield range of 500-1000 t for the central west coast of Vancouver Island stock.

The yellowtail rockfish fishery off the southwest coast of Vancouver Island appears to exploit a biomass that is shared with the U.S. fishery in northern Washington. We present a yield range for this transboundary stock of 1000-2000 t. The WDF biologists recommends an "Acceptable Biological Catch" of 2000 t. The biology of the species does not appear to pertain to the allocation issue.

Inshore rockfish

The escalation of the line fishery for inshore rockfish in the Vancouver-Charlotte Region has continued. Stocks were assessed by historical trends in CPUE and by changing size and age structure of populations from commercial samples. Stock condition was determined to be poor in heavily exploited areas. Yields were estimated to range from 505-1665 t in 1990.

Hagfish

The experimental hagfish fishery is new in B.C. and information on the life history and population parameters of hagfish is sparse. Catch statistics were summarized for the fishing period (October 1988 June 1990) and decreases in CPUE documented. It is recommended that the fishery remain classified as experimental until more information on their biology is known. Also, although expansion of the fishery into areas other than 23-27 and 123 is acceptable, limits on effort within each area should be maintained.

1.6. YIELD OPTIONS AND CATCH STATISTICS

Catch limitations

A number of levels of yield options are presented. All may not be appropriate to apply to a particular species or stock. The seven yield options are: (i) zero yield; (ii) rebuilding yield; (iii) sustainable; (iv) low risk-sustainable; (v) high risk-sustainable; (vi) non-sustainable and (vii) unrestricted yield. Yield options are defined in the previous year's assessment document (Section 1.6 In: Fargo and Tyler [ed.] 1990).

Other measures

The trawl fishery for groundfish is characterized by a multi-species catch. Managers, biologists, and vessel captains have noted that there are two principal difficulties created because of the multi-species characteristics. (1) Biological interactions among species may interfere with the simultaneous maximization of fisheries potential yield in all co-existing species. (2) Where there are several annual quotas on a group of co-existing species, the species quota that is taken first could close down fishing on the entire group. At present biological interactions are not explicitly built into the stock assessments. This is cause for avoiding the high risk-sustainable options if at all possible. Trip limits have been used to spread the take of lower production species through the year. In a few cases, species-mixture or group quotas are given, and an area is not closed until the group quota is reached. Species ratios are checked for imbalance. If a gross imbalance is found, the group quota is adjusted the following year.

Catch statistics

In this document we use the terms NOMINAL CATCH and NOMINAL CPUE (or just CPUE), following the definitions outlined in the FAO Yearbook of Fishery Statistics, to refer to round weights of fish landed by vessels in port. These terms are defined in detail in the previous year's assessment document (Section 1.7 In: Tyler and Fargo [ed.] 1990).

1.7 Recommendations for management of west-coast groundfish for 1990 based on biological considerations only are summarized below.

Area	Species	Management options
4B Areas 13-20 20, 28, 29	Lingcod*	Total closure of sport and commercial fisheries.
Area 12	Lingcod*	1. Winter closure Nov. 15-Apr. 30. 2. Size limit of 65 cm.
3C	Lingcod*	1. Winter closure Nov. 15-Apr. 30. 2. Sustainable: 2000 t 3. Size limit of 65 cm.
3D	Lingcod*	1. Winter closure Nov. 15-Apr. 30. 2. Size limit of 65 cm. 3. Sustainable: 600 t.
5A/B	Lingcod*	1. Size limit of 65 cm for commercial fishery. 2. Sustainable: 2000 t
5C/D/E	Lingcod	1. Winter closure Nov.15- Apr. 30. 2. Size limit of 65 cm.
4B	Pacific cod	No options proposed.
3C/3D	Pacific cod	Open fishing due to average abundance and moderate fishing effort.
5A/5B	Pacific cod	No options proposed.

Area	Species	Management Options
5C/5D	Pacific cod*	Open fishing due to strong recruitment, average abundance and moderate fishing effort.
5E	Pacific cod	No options proposed.
Coastwide	Petrale sole	1. Sustainable: trip limit 44,000 lb.
4B	Flatfish	No options proposed.
3C/D	Dover sole*	Low risk sustainable: 500 t. Sustainable: 1300 t. High risk sustainable: 2000 t.
5A	Rock sole*	1. Low risk sustainable: 250 t (with 30,000 lb trip limit). 2. Sustainable: 375 t. 3. High risk sustainable: 500 t.
5B	Rock sole*	1. Low risk-sustainable: 250 t with a 30,000 lb trip limit. 2. Sustainable: 425 t, 30,000 lb trip limit. 3. High risk-sustainable: 600 t.
5C	Rock sole*	1. Low risk-sustainable: 100 t. 2. Sustainable: 250 t, 3. High risk-sustainable: 400 t. with a 30,000 lb trip limit.

Area	Species	Management options
5D	Rock sole*	1. Low risk-sustainable: 800 t, 30,000 lb trip limit 2. Sustainable: 900 t, trip limits as in 1. 3. High risk-sustainable: 1000 t.
5C/D	English sole*	1. Low risk-sustainable:700t. 2. Sustainable: 850 t 3. High risk-sustainable: 1000 t.
5C/5D/5E	Dover sole	1. Low risk-sustainable: 800t quota, 20,000 lb/trip permitted after 75% of the quota is reached. 2. Sustainable: 1000 T. trip limit as above. 3. High risk-sustainable: 1,200 t quota trip limit as above.
Coastwide	Sablefish	1. Low risk-sustainable: 2,900 t quota. 2. Sustainable: 4,000 t. 3. High risk-sustainable: 5,000 t quota.
4B, except MSA 19, 20	Pacific hake	1. Low risk-sustainable: 8,000 t. 2. Sustainable: 11,000 t. 3. High risk-sustainable: 14,000 t.
3C-D*	Pacific hake	1. Low risk-sustainable: 175,000 t 2. Sustainable: 253,000 t 3. High risk-sustainable: 311,000 t

*These tonnages are the stock quotas for the U.S. and Canada combined. Allocation between nations will be determined by the managers.

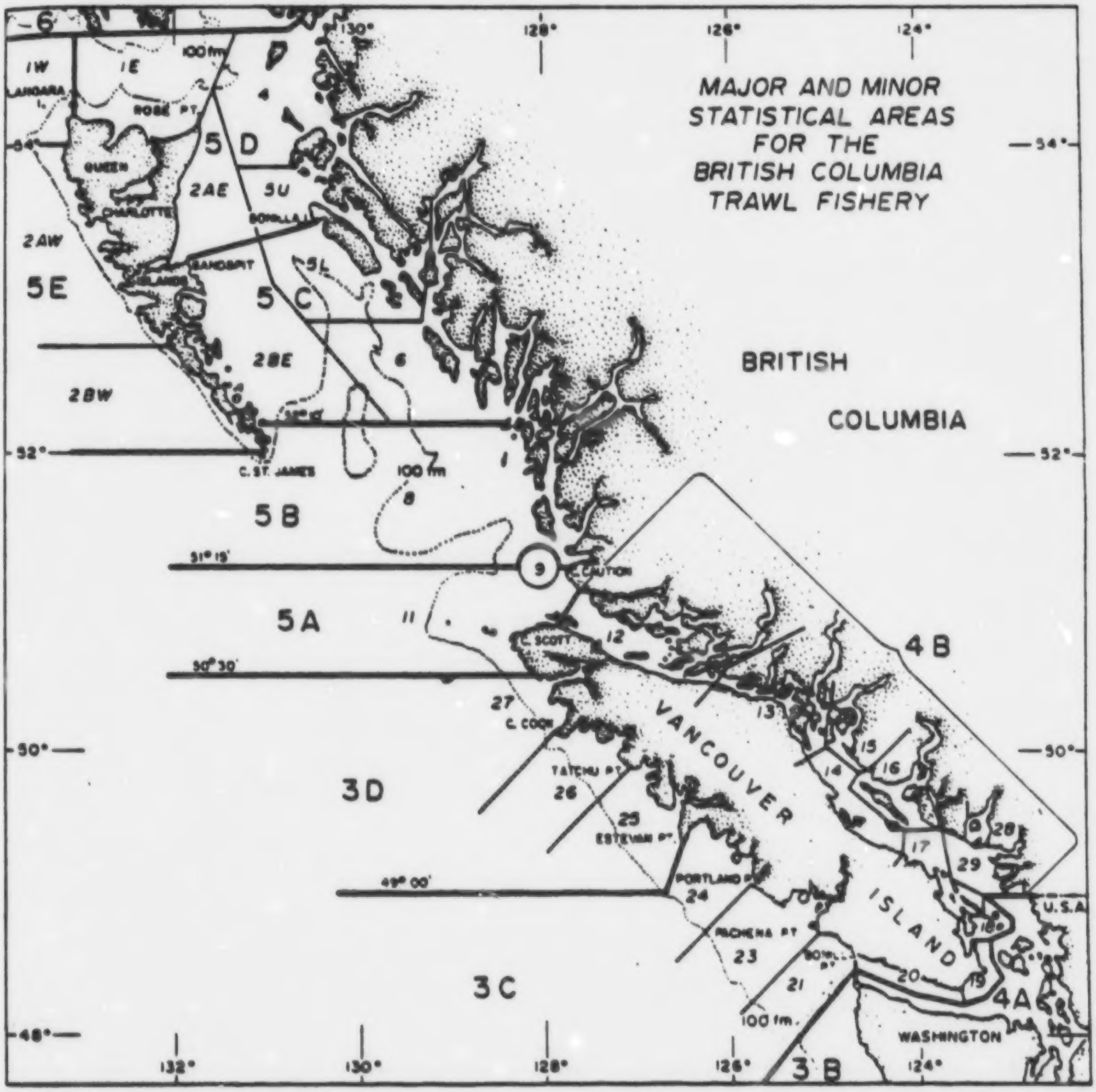
Area	Species	Management options
Coastwide	Dogfish	1. Pulse fishing: variable annual (not including 4B) quota until non-nuisance abundance reached. 2. Low risk-sustainable: 15,000 t in 3 and 4 quarter of year only. 3. Low risk-sustainable alternative: 9,000 t in 1 and 2 quarter of years only. 4. High risk-sustainable: 25,000 t in 3 and 4 quarter only. 5. High risk-sustainable alternative: 15,000 t in 1 and 2 quarter of years only.
4B, not including annual MSA 12, 19, 20.	Dogfish	1. Low risk sustainable: 2,000 t. 2. Sustainable: 2,500 t. 3. High risk-sustainable: 3,000 t.
4B	Walleye pollock	1. Low risk-sustainable: 2,500 t quota. 2. High risk-sustainable: 5,400 t quota.
3C/3D	Walleye pollock	Options not proposed.
5A/5B	Walleye pollock	Options not proposed.
5C/5D	Walleye pollock	Open fishing option proposed.
5E	Walleye pollock	Options not proposed.

Area	Species	Management
3B-3C* *Combined U.S. & CDN. quota	Yellowtail rockfish*	Low risk sustainable 1000 High risk sustainable 2000
3D	Yellowtail rockfish	Low risk sustainable 500 High risk sustainable 1000
5A/5B	Yellowtail rockfish	Low risk sustainable: 1400 t High risk sustainable: 3000 t.
3C/3D	Silvergray rockfish	Low risk-sustainable: 400 t. High risk-sustainable: 600 t.
5A/5B	Silvergray rockfish*	Low risk sustainable 200 t High risk-sustainable: 700 t
5C/5D	Silvergray rockfish	Low risk sustainable 400 t High risk-sustainable: 600 t.
5E-S	Silvergray rockfish	No recommendation. Currently an incidental fishery. No trip limit should apply
3C/3D	Canary rockfish	Low risk-sustainable: 400 t High risk-sustainable: 600 t

Area	Species	Management options
5A/5B	Canary rockfish	Low risk-sustainable: 350 t High risk-sustainable: 500 t
3C options (including Area 125)	Pacific ocean perch	1. Rebuilding:<100 t 2. Low risk-management sustainable:100 t 3. High risk-sustainable 200 t
3C	Redstripe rockfish	Low risk-sustainable:200 t High risk sustainable: 1,000 t
3D	Pacific ocean perch	Low risk-sustainable:200 t High risk-sustainable:600t
3D/5A	Yellowmouth	Low risk-sustainable:250 t High risk-sustainable:750t
3D/5A	Redstripe	Low risk-sustainable:350 t High risk-sustainable:900t
5A/5B	Pacific ocean perch	Rebuilding:<700 t Low risk-sustainable:700 t High risk-sustainable: 1,000 t
5C/5D	Pacific ocean perch	Low risk-sustainable: 1,900 t High risk-sustainable 3,000 t
5C/5D	Yellowmouth	Low risk-sustainable:160 t High risk-sustainable:500t

Area	Species	Management options
5C/5D	Redstripe	Low risk-sustainable:350 t High risk-sustainable:570t
5E-S	Pacific ocean perch	Low risk-sustainable:300 t High risk-sustainable:500t
5E-S	Yellowmouth	Low risk-sustainable:400 t High risk-sustainable:700t
5E-S	Rougheye	Low risk-sustainable:200 t High risk-sustainable:300t
5E-S	Grouped slope rockfish (Pacific ocean perch, yellowmouth and rougheye)	January-June Low risk-sustainable:300 t High risk-sustainable:500t September-December Low risk-sustainable:600 t High risk-sustainable: 1,000t
5E-S	Redstripe	Low risk-sustainable:50 t High risk-sustainable:100t
5E-N	Pacific ocean perch	Low risk-sustainable:150 t High risk-sustainable:170t
5E-N	Yellowmouth	Low risk-sustainable:350 t High risk-sustainable:500t
5E-N	Rougheye	Low risk-sustainable:50 t High risk-sustainable:100t

Area	Species	Management options
5E-N	Redstripe	Low risk-sustainable:500 t High risk-sustainable:700t
4B 12-20, 28, 29	Yelloweye	Sustainable:50 t Includes sport fishery
4B 12-20, 28, 29	Grouped line rockfish, except yelloweye	Sustainable:400t Includes sport fishery
11, 21-27, 121-127, 111	Grouped line rockfish*	Sustainable:400t Includes sport fishery
6-10, 106-110	Grouped line rockfish*	Sustainable:200t Includes sport fishery
3-5, 103-105	Grouped line rockfish*	Sustainable:100t Includes sport fishery
1,2,101,102,130, 142	Grouped line rockfish*	Sustainable:300t Includes sport fishery


MAJOR AND MINOR
STATISTICAL AREAS
FOR THE
BRITISH COLUMBIA
TRAWL FISHERY
BRITISH
COLUMBIA
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1W
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ROSE PT.
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2BW
C. ST. JAMES
100 fm
7
8
1
5B
51°15'
9
C. CAUTION
5A
11
C. SCOTT
12
50°30'
27
C. COOK
VANCOUVER
ISLAND
13
14
15
16
4B
3D
TATCHU PT.
26
25
ESTEVAN PT.
49°00'
PORTLAND PT.
24
PACHENA PT.
23
BONILLA PT.
21
20
17
28
29
18
19
U.S.A.
4A
3C
100 fm.
WASHINGTON
3B
130°
128°
126°
124°
132°
54°
52°
50°
48°

Fig. 1.1. International major statistical areas along the British Columbia coast designated by the Groundfish Technical Sub-committee of the Pacific Marine Fisheries Commission.

REVIEWER ASSIGNMENTS FOR GROUNDFISH STOCK ASSESSMENTS

Title	Authors	Reviewers
Lingcod	Richards, Hand	Leaman, McFarlane
Pacific cod	Foucher, Tyler	Leaman, Saunders
Flatfish	Fargo	Hand, Noakes
Sablefish	Saunders, McFarlane	Stanley, Fargo
Dogfish	Thomson, Saunders	Tyler, Richards
Walleye pollock	Saunders, Workman	Stanley, Tyler
Pacific hake	Saunders	Hand, Fargo
Slope rockfish	Richards	Tyler, Fargo
Shelf rockfish	Stanley	Saunders, Richards
Inshore rockfish	Richards, Hand	Thomson, Starr
Hagfish	Neville, Beamish	Thomson, Tyler

PARTICIPANTS AT THE GROUNDFISH SUBCOMMITTEE MEETING
August 30, 31, 1990

A. Tyler, Chairman
D. Adams
G. Beuchler
J. Fargo
S. Farlinger
C. Hand
R. Harbo
B. Leaman
D. McKone
G. McFarlane
C. Neville
D. Noakes
M. Saunders
R. Stanley
P. Starr
G. Thomas
B. Thomson
L. Richards
N. Venables
G. Workman
L. Yamanaka

2.0 LINGCOD

by L. J. Richards and C. M. Hand

2.1 Strait of Georgia and vicinity (Area 4B)

2.1.1 The Fishery

The commercial lingcod fishery began in the Strait of Georgia in the early 1900s (Fig. 2.1). The maximum reported catch of approximately 3300 t occurred in 1944. Catch remained high through the 1940s and 1950s, but has declined gradually since the 1960s. The 1989 value of 74 t is the lowest recorded.

Historically, most of the commercial catch was taken by handline/troll gear, with minor catches by longline and trawl gears (Table 2.1). Fishing activity was concentrated near Campbell River (statistical area 13), Pender Harbour (area 16), and the northern Gulf Islands (area 17) (Table 2.2). Landings in all areas have declined in recent years to insignificant amounts, with the exception of area 12 where landings have increased marginally. These area 12 landings are probably incidental to the rockfish handline fishery. Larger landings occurred in area 12 during the 1960s and early 1970s.

The sport angling fishery has been monitored since 1980 by creel and overflight surveys (Shardlow and Collicutt 1989a-e; Shardlow et al. 1989, 1990). These surveys provide estimates of the numbers of lingcod caught by anglers by statistical area (Table 2.3). The sport angling catch averaged 128 t annually between 1980-85, with the exception of 1984 when the estimated catch was 220 t. The sport catch has decreased since 1985 to a low of 84 t in 1989. Because of the even greater decline of the commercial fishery, however, the sport fishery is taking an increasing share of the total lingcod catch. In fact, the sport angling catch has exceeded the comparable commercial handline/troll and longline catch since 1984 (Fig. 2.2). In 1989, the sport fishery accounted for 69% of the total line catch from statistical areas where the creel survey was conducted.

Lingcod are also the target of an underwater spear fishery. A survey of the diving community in the Strait of Georgia was conducted in the fall of 1983 to provide estimates of diving effort and collecting activities, including spearfishing (McElderry and Richards 1984). Approximately 50% of the divers surveyed made dives for the purpose of spearfishing. The lingcod spearfishing catch was very roughly estimated at 80 t for 1983, or 65% of the annual sport angling catch. Some of these landings are likely included in catch estimates from the creel survey but they are not identified as such.

A winter (Dec.-Feb.) closure to commercial fishing was in effect as early as 1940 (Ketchen et al. 1983) to protect lingcod spawning stocks. In 1979, the existing closure (Dec. 31-Mar. 31) was extended (Nov. 15-Apr. 15) for both commercial and sport fishing. This was an attempt to further protect the pre-spawning aggregations and nest-guarding males, and hence, to improve recruitment. Various measures continued to indicate a decline in lingcod abundance (Richards and Hand 1988). In 1988, the closure period was extended to April 30. In addition, subareas near Campbell River (13-1 to 13-9, 13-11, and 13-27) were closed to commercial fishing. In 1990, the commercial fishery was closed entirely in all areas except area 12. In addition, a 58 cm voluntary size limit was implemented for the sport fishery, corresponding to the coastwide commercial size limit. The sport fishery has also been restricted to a bag limit of 3 fish/d.

2.1.2 Catch Statistics

Catch and effort statistics from sales slip data files have been available from the Department of Fisheries and Oceans (Fisheries Branch, Statistics Division) since 1967. Between 1951 and 1967, catch statistics were available only in the annual reports published by the Statistics Division. Between 1918 and 1951, lingcod landings were reported in Fisheries Statistics of Canada, Dominion Bureau of Statistics. Prior to 1918, catch information, with all 'cod' lumped together, was recorded in Annual Reports of the Department of Fisheries. A correction factor, based on average proportions of blackcod and lingcod in the catch from 1918-1930, was applied to the 'cod' landings prior to 1918 to obtain a more accurate estimate of the lingcod catch.

Catch per unit effort (CPUE), an abundance index, is determined from handline/troll and longline catch and effort data only, since trawl landings have traditionally been unimportant. Historically, most of the commercial handline/troll and longline fishery in Area 4B was targeted on lingcod. Since the late 1970s, however, increased effort has been directed at rockfish. To avoid including directed rockfish effort in the lingcod analysis, CPUE is determined from sales slip records with a reported lingcod handline/troll or longline catch of at least 100 kg (Richards and Hand 1988). Effort is determined from the ratio of the combined line catch to CPUE.

CPUE for Area 4B lingcod averaged 170 kg/d between 1967-80, and has since declined (Table 2.4). The 1989 rate of 48 kg/d was a slight increase over the extremely low 1988 rate of 41 kg/d. Decreases in catch, effort, and the number of commercial vessels targeting on lingcod have been coincident with the decrease in CPUE (Fig. 2.2). All of these factors are indicative of major decreases in lingcod abundance. The proportion of the total line catch that meets the criterion for inclusion in the CPUE calculation has also decreased, suggesting that the true declines in CPUE may be underestimated. A greater proportion of the lingcod catch is now taken incidentally to other line fisheries such as the inshore rockfish fishery.

Declines in lingcod abundance are also evident from trends in CPUE by statistical area (Table 2.4). For area 13, CPUE averaged 269 kg/d between 1967-80 and then declined to the 1988 low of 31 kg/d, with a slight increase to 44 kg/d in 1989. The high values of CPUE between 1971-76 were associated with unusually low effort. The values of CPUE for recent years are low in spite of low effort, however. The pattern is similar for area 17. CPUE remained fairly stable around 158 kg/d between 1967-80, even though effort declined during this period. CPUE, catch and effort have all since declined, although the decline has been less dramatic than in area 13. The higher 1989 value of CPUE in area 17 is somewhat misleading as it is based on a catch of less than 5 t.

2.1.3 General Biological Information

Biological samples of the commercial handline fishery have been collected sporadically since 1957. Sampling has become increasingly difficult due to the small size of the commercial catch. Samples from statistical areas 13 and 17 are available intermittently for 1979-84. Mean size of male and female lingcod decreased over this period in both areas (Table 2.5). In addition, one sample was collected from area 13 in 1988 by an observer. The mean length (63 cm) was considerably smaller than previous samples, and 46% of the total catch was smaller than the size limit. Large fish (>80 cm) were completely absent from the sample.

The biological sample data from 1957-84, supplemented by 1985-88 research survey data (Hand and Richards 1987, 1989) and growth estimates (Schnute et al. 1989a) may be used to estimate annual survival (Schnute et al. 1989b). The survival estimates apply only to the sizes of fish caught by the commercial fishery. Annual survival estimates are 76% for early samples obtained between 1957-70, 79% for samples obtained between 1979-84, and 71% for the most recent samples obtained between 1985-88. The overall estimate of annual survival is 76%, based on all samples obtained between 1957-88. The overall estimate is consistent with the value of 76% ($Z=0.28$) obtained for the Area 3C lingcod stock (Section 2.2.4). Survival appears to be high for lingcod in the size range available to the commercial fishery. However, there appears to have been a decrease in survival since 1984.

Alternative estimates of survival are available from a mark-recapture experiment conducted in the Strait of Georgia between 1982-87. Smith et al. (1990) estimated 95% confidence intervals of annual survival to be 29-49% and 46-75% for male and female lingcod, respectively. Their analysis is based on tag returns from the sport fishery only, which targets more heavily on the male and small female lingcod found on shallow reefs. Their lower estimated survival rates, particularly for males, may be a reflection of the intense mortality inflicted on smaller fish by the sport fishery. They may have underestimated survival somewhat, however, due to gear selectivity. Cass and Richards (1987) and Hand and Richards (1987, 1989) compared lingcod catches by sport angling and commercial gear from the same vessel at the same time. They obtained significantly lower values of CPUE and caught significantly smaller fish with angling gear.

Richards et al. (1990) completed an analysis of size at maturity for the offshore lingcod stocks. Following their methodology, size at maturity can be obtained for Area 4B female lingcod, based on research survey data from 1985-88 (Cass and Richards 1987; Hand and Richards 1987, 1989). Size at 50% maturity for females is 67.4 cm with a 95% confidence interval of 65.6-69.2 cm. This is significantly larger than the current commercial size limit of 58 cm, which approximates size at 20% maturity.

Since 1983, length and sex information for the lingcod sport catch have been collected during the creel survey. Mean fish size has remained fairly constant over the 1983-89 period (Table 2.5). The sport fishery takes a different component of the lingcod stock than the commercial fishery. Most (66%) of the sport-caught fish are smaller than the commercial size limit of 58 cm (Fig. 2.3). In addition, 83% of the sport-caught fish (62% of the biomass) are smaller than the recommended size limit of 65 cm.

In the absence of a commercial fishery, information with which to assess lingcod stocks must come from fishery-independent sources. To that end, surveys of post-larval and juvenile lingcod are ongoing, as well as investigations of lingcod reproductive behaviour and movement. A survey of nesting lingcod in 1990 found no nests at the site of a previous survey in 1977-78 (Low and Beamish 1978), although nests were located in other areas. Preliminary results from post-larval surveys conducted in 1989-90 suggest that recruitment has decreased since a similar survey in 1980-81 (Cass and Scarsbrook 1984).

In April 1990, ultrasonic tags were used to monitor home ranges and possible homing routes of 11 lingcod on rocky reefs off Gabriola and Valdes Islands. Six lingcod were tagged and released at their capture site. These lingcod remained on the reef, although they were more active at night. To determine whether lingcod home, five male lingcod were moved up to 2.75 km and monitored as they returned to their capture site. Four lingcod returned within 24-72 h. The smallest lingcod (57 cm) remained at the release site for 1 wk after being moved 2.25 km. Homing lingcod only moved during the night and returned to the exact site of their capture. Once relocated at their original capture site, no subsequent movement was detected. These short-term results may reflect nesting behavior, as the experiment was conducted at the end of the nesting season. In a recent analysis of mark-recapture data, Smith et al. (1990) reported movements of up to 99 km for a male lingcod (65 cm) that was recaptured after 185 d. They further concluded that movement rates were sufficient to consider lingcod populations in the Strait of Georgia as a single stock.

2.1.4 Condition of the Stock

The Strait of Georgia lingcod stock has continued to decline since the early 1960s. Commercial catch, CPUE, effort, the number of vessels targeting on lingcod, and mean lingcod size have all decreased (Table 2.4), and the rate of decline appears to have accelerated over the last 5 yr. In addition, the sport catch has decreased since 1984 (Fig 2.2). Similar declines are evident in northern Puget Sound lingcod populations, based on trends in sport fishing catch rates (G. Bargmann, WDF, pers. com.). The Strait of Georgia lingcod stock is now at an extremely low level of abundance.

Although there is strong evidence that the lingcod stock has declined, the cause of the decline is less clear. Overfishing is suspect, given the large catches during the early part of the commercial fishery and the present large catch of immature fish by the sport fishery. The decline could also be related to changes in lingcod predator abundance, food abundance, or other aspects of habitat quality, poor recruitment associated with a small spawning stock, or any combination of these factors.

Sea mammal predation on lingcod is significant. Preliminary investigations indicate that sea lion predation amounts to 41 t of lingcod, including both the Strait of Georgia and the southwest coast of Vancouver Island (P. Olesiuk, pers. comm.). Since 1970, the harbour seal population has increased at an annual rate of 12.5% (Olesiuk et al. 1990a). Lingcod account for 3% of the harbour seal diet, which amounts to an estimated annual consumption of 294 t of lingcod (Olesiuk et al. 1990b). As the increase in the harbour seal population is relatively recent, it is unlikely that they are responsible for the long-term decline in lingcod abundance. However, they are a factor in maintaining the stock at its current low level. Lingcod are preyed on primarily during November-April when the males are particularly vulnerable.

Smith et al. (1990) concluded that commercial fishing effort resulted in the initial stock decline, with sea mammal predation and the sport fishery now inhibiting stock rebuilding. Furthermore, they stated that an increase in sport fishing effort was the greatest threat to the lingcod stock. From their analysis of movement rates, they suggested that lingcod populations near heavily exploited areas are maintained by migration from more remote areas, thus broadening the impact of localized fisheries.

2.1.5 Yield Options

Whatever the cause of the decline, it is apparent that the Strait of Georgia lingcod stock cannot sustain the levels of exploitation experienced through 1989. Serious measures are now required to prevent further stock collapse and to allow the stock to begin rebuilding. The management strategy must involve both sport and commercial fisheries. It is recommended that the Strait of Georgia (areas 13-20, 28, 29) be closed to all gear types (sport and commercial), with no incidental catch permitted. As most lingcod do not mature until age 4-5 yr, the closure must be maintained for at least 5 yr to be effective. A winter closure (Nov. 15 - Apr. 30) and a 65 cm size limit are recommended for the area 12 lingcod fishery.

2.2 West Coast Vancouver Island (Areas 3C and 3D)

2.2.1 Introduction

Lingcod off the west coast of Vancouver Island are assumed to exist as two discrete stocks or groups of stocks, one off southwest Vancouver Island (Area 3C), and one off northwest Vancouver Island (Area 3D). Analyses and catch statistics are presented by major statistical area.

2.2.2 The Fishery

Lingcod stocks off southwest Vancouver Island are exploited by trawl, hook and line, and recreational fisheries. There have also been undocumented and presumably small catches by Indian food fisheries and foreign national (other than United States) fisheries. The hook and line fishery includes a targeted longline fishery and incidental catches by salmon troll vessels. The commercial trawl fishery accounts for the majority of the lingcod catch. Prior to 1987, there were no legal restrictions on the commercial lingcod catch, except for occasional winter closures and a size limit of 58 cm, implemented initially as a weight limit, in 1942. Lingcod catch has been limited in the past by low market demand. In 1987, a 1400 t quota was placed on the Area 3C lingcod catch, due to concerns over low stock abundance.

2.2.3 Catch Statistics

The compilation of lingcod catch statistics for Area 3C is described in Cass et al. (1988). Briefly, CPUE is calculated from interviewed trawl landings between May-September. A catch is included only if lingcod account for at least 25% of the total catch weight, and the vessel used double gear. Effort recorded for the catch is then standardized for vessel horsepower class (Westrheim and Foucher 1985, Table 8). In addition, the proportion of the catch that could be accounted for by lingcod above a defined weight of 2.25 kg is determined annually from biological samples. The defined weight was chosen to approximate weight at recruitment to the fishery. CPUE is the ratio of the sum of the qualified catch to the sum of the qualified effort, corrected by the proportion of fish of recruitment weight or greater. Effort is the ratio of total all-gear catch to the corresponding CPUE.

The Area 3C lingcod commercial catch has varied between 500-3600 t (Table 2.6, Fig. 2.4). In 1989, trawl catch increased 33% to 839 t from the low 1988 catch of 566 t. The 1989 line catch of 121 t was similar to the 1988 catch of 113 t. Line catch (combined handline/troll and longline) has tended to be less variable than trawl catch and has averaged 184 t between 1956-89. The total 1989 catch was 960 t, considerably below the historical average of 1368 t. CPUE increased during 1988-89 over the low 1987 value and is now approaching the historical average of 323 kg/h.

In 1988-89, the lingcod sport catch in Barkley Sound and Alberni Inlet was monitored by a creel survey. The estimated sport catch in 1988 was 4,372 fish with a mean size of 60.1 cm (Table 2.5). This amounts to approximately 9 t. The estimated sport catch in 1989 was 8,853 fish, or approximately 22 t, with a mean size of 64.5 cm.

Commercial landing statistics for Area 3D have been compiled in a manner similar to the Area 3C statistics. In years for which there are no Area 3D biological samples, the proportion of fish of recruitment weight or greater in the catch is estimated from the Area 3C samples. CPUE calculated by this method from qualified trawl catch is a less useful abundance index for Area 3D than for Area 3C, because the line catch accounts for a higher proportion of the total Area 3D catch. For example, only 10, 7, and 20% of the total catch met the qualification requirements in 1986, 1987, and 1988, respectively.

The lingcod catch from Area 3D has ranged from a low of 166 t in 1959 to a high of 985 t in 1968 (Table 2.6, Fig. 2.4). The 1989 catch of 476 t was above the historical average of 408 t. Unlike Area 3C, line catches have increased in Area 3D. Line catches between 1986-88 are the highest on record, although there was a slight decline in 1989. CPUE decreased slightly in 1989 to 225 kg/h.

2.2.4 General Biological Information

A comparative analysis of size and age at maturity for the Area 3C and Queen Charlotte Sound (Section 2.4.4) lingcod stocks was completed in 1989 (Richards et al. 1990). In general, male lingcod mature at a smaller size, but not necessarily a younger age, than do female lingcod. In addition, size and age at maturity tend to increase with latitude for each sex. The current commercial size limit of 58 cm falls between length at 20 and 50% maturity for male lingcod, but is smaller than length at 20% maturity for female lingcod. The 95% confidence interval for length at 50% maturity for female Area 3C lingcod is 63.5-64.7 cm.

Schnute et al. (1989b) present a detailed analysis of lingcod survival between 1956-86, based on the time series of catch, CPUE, and biological sample data for the Area 3C commercial fishery. Updating the analysis to include data for 1987-89 results in only minor changes to the survival estimates from their statistical model. The estimate of the mean mortality rate (Z) over the 1956-88 period is 0.28. Unfortunately, the model is somewhat uncertain in attributing the total mortality between fishing (F) and natural mortality (M). For example, the 95% confidence interval for M ranges from 0.06-0.36. If M=0.22, a reasonable assumption for a fish that lives about 20 yr, then the estimate for F in 1989 is 0.04 with a corresponding population size estimate of 20 kt. However, as the 95% confidence interval for F includes 0, the population size is poorly determined. Schnute et al. (1989b) noted a possible decline in recruitment over the last 10-15 y. The value of the recruitment index for 1989 is the highest recorded since 1969 (Fig. 2.5).

Although fewer data are available for Area 3D, parameter estimates obtained from the statistical model are essentially identical to those for Area 3C. The estimate for mean annual mortality (Z) over the 1956-89 period is 0.28 and the 95% confidence interval for natural mortality (M) is 0.14-0.39. If M=0.22, then the estimate for F in 1989 is 0.10 with a corresponding population size of 5 kt. However, as for Area 3C, the 95% confidence interval for F includes 0, indicating that F and the population size are poorly determined.

2.2.5 Condition of the Stock

Based on CPUE, Area 3C lingcod stocks have increased since the low in 1987 and are now nearing average levels of abundance (Fig. 2.4). In addition, recruitment appears to have increased in 1989 (Fig. 2.5). Caution is still warranted for this stock, however. The experience in the Strait of Georgia has shown that lingcod are susceptible to over-exploitation. The current size limit of 58 cm is much smaller than the size at 50% maturity for female lingcod. Since 1986, catches have been well under the current quota of 1400 t.

2.2.6 Yield Options

Two types of yield options are proposed, a change in the size limit and a quota. In both cases, it is recommended that the winter fishing closure (Nov. 15 - Apr. 30) be maintained to protect nesting lingcod.

(A) It is recommended that the commercial size limit be increased to 65 cm to more accurately reflect size at maturity for female lingcod. Approximately 22% of the lingcod caught by the commercial fishery in Area 3C fall below the proposed size limit. As size distributions are highly variable between samples in any year, it is likely that vessels can target areas with larger fish.

(B) It is recommended that catches not exceed the sustainable level of 2000 t for Area 3C and 600 t for Area 3D. The sustainable yield was determined from the mean of the group of historical catches that were greater than the long-term mean of 1400 t for Area 3C and 400 t for Area 3D.

2.3. Queen Charlotte Sound (Areas 5A and 5B)

2.3.1 Introduction

Commercially exploited lingcod stocks are located on the Cape Scott (Area 5A) and Goose Island (Area 5B) grounds. As few commercial samples are available for Area 5A lingcod, and as catch trends are similar in both areas, lingcod in Queen Charlotte Sound are treated as one stock for this assessment.

2.3.2 The Fishery

Lingcod stocks in Queen Charlotte Sound are primarily exploited by commercial trawl vessels. There are also small catches by hook and line vessels. Queen Charlotte Sound is the area with the greatest fishery production for lingcod, although lingcod have generally been a minor component of the total trawl fishery.

2.3.3 Catch Statistics

The compilation of catch statistics for Area 5A/B is similar to that discussed for Area 3C (section 2.2.3). CPUE for Area 5A and 5B is calculated from 25% qualified interviewed trawl catch between May-September. Qualified effort is standardized for vessel horsepower class (Westrheim and Foucher 1985, Table 8). CPUE for Area 5A/5B combined is also corrected for a weight at recruitment to the fishery of 2.25 kg, based on the average weight-frequency distribution of the 1956-87 commercial samples (Richards and Hand 1988). Effort is calculated from the ratio of catch to CPUE.

Catch from Area 5A and Area 5B contributed about equally to the Area 5A/B total between 1956-70 (Table 2.7, Fig. 2.6). Since 1970, catch has been greater from Area 5B, although 1987 and 1989 are exceptions. In general, trends in trawl catch and CPUE have remained similar in the two areas. However, the line catch has been increasing in Area 5A and the 1989 catch of 124 t is the highest recorded. The 1989 total Area 5A/B catch of 1759 t is the second highest recorded. CPUE has been above the 1956-89 average since 1986.

2.3.4 General Biological Information

As discussed in Section 2.2.4, an analysis of size and age at maturity was completed for the Queen Charlotte Sound stocks (Richards et al. 1990). Male lingcod from Area 5A and 5B mature at a larger size than do male lingcod from Area 3C.

Similarly, female lingcod from Area 5B mature at a larger size than do female lingcod from Area 3C and 5A. Confidence intervals (95%) for size at 50% maturity are 64.4-66.6 cm and 66.0-67.0 cm for female lingcod from Area 5A and 5B, respectively.

Estimates of mean annual survival may be obtained for the Area 5A/B stock as described in Schnute et al. (1989b), using the growth estimates derived for the 1988 assessment (Richards and Hand 1989). The estimate for mean total mortality (Z) is 0.20, with an approximate 95% confidence interval of 0.14 to 0.27. This range is below the corresponding estimate of Z=0.28 for Area 3C and suggests that the stock has experienced a low fishing mortality.

2.3.5 Condition of the Stock

Stocks in Area 5A/B appear to be sustainable at current rates of exploitation. The estimated total mortality rate is low and CPUE has remained high.

2.3.6 Yield options

The 1989 catch of 1759 t is higher than the high-risk sustainable yield of 1400 t from previous assessments. As the stock still appears to be at above-average levels of abundance, the previous yield values are probably too low. However, the highest recorded catch of 2298 t in 1968 led to a large drop in CPUE in 1969. Thus, the sustainable yield should be between 1759 and 2298 t. It is recommended that the catch not exceed the sustainable yield of 2000 t from this area. In addition, it is recommended that the size limit be increased to 65 cm and a winter closure (Nov. 15 - Apr. 30) be implemented.

2.4 Areas 5C/D/E

2.4.1 Yield options

Assessments are not conducted for these areas. However, it is recommended that the size limit be increased to 65 cm to complement the size limit for other offshore areas. The State of Alaska now has a commercial size limit of 27 in (69 cm), imposed due to increased targeting on small fish (Bracken 1989). Furthermore, a winter fishing closure (Nov. 15 - Apr. 30) is recommended to prevent strongly biased sex ratios in the catch.

Table 2.1. Lingcod handline/troll catch (t), longline catch (t), trawl catch (t), and total catch (t) for Area 4B, 1951-89.

Year	Handline/troll[a]	Longline[a]	Trawl[b]	Total
1951	1279.5	27.4	48.1	1355.0
1952	1488.8	17.2	54.0	1560.0
1953	1179.2	6.3	28.1	1213.6
1954	1449.4	9.4	69.2	1528.3
1955	1220.1	8.5	50.6	1279.2
1956	1512.1	9.6	55.7	1577.4
1957	1539.7	4.5	42.0	1586.2
1958	1445.6	4.0	74.6	1524.2
1959	1183.0	6.7	336.4	1526.1
1960	1250.6	21.4	184.1	1456.1
1961	1157.7	30.7	102.1	1290.5
1962	1272.8	14.3	75.7	1362.9
1963	989.3	9.3	39.7	1038.3
1964	870.4	5.5	90.3	966.2
1965	779.7	6.5	93.8	880.0
1966	771.3	20.0	56.0	847.3
1967	781.0	14.5	54.4	849.9
1968	729.8	12.5	94.6	836.9
1969	747.9	19.9	65.6	833.4
1970	792.0	31.3	48.8	872.1
1971	564.9	34.3	60.5	659.7
1972	513.4	10.3	34.7	558.4
1973	373.1	31.2	15.0	419.3
1974	354.7	16.2	49.4	420.3
1975	331.4	37.3	33.9	402.6
1976	316.0	15.3	43.6	374.9
1977	408.7	24.9	32.1	465.7
1978	445.2	56.5	42.7	544.4
1979	505.5	56.0	26.6	588.1
1980	342.1	12.0	38.2	392.3
1981	334.5	9.2	67.1	410.8
1982	358.8	11.4	196.6	566.8
1983	274.7	12.6	135.4	422.7
1984	182.7	10.4	90.6	283.7
1985	129.2	8.6	34.0	171.8
1986	99.1	16.1	44.5	159.7
1987	71.3	9.2	17.2	97.7
1988	76.3	7.2	13.3	96.8
1989	56.9	14.5	2.8	74.2

[a] British Columbia Catch Statistics, Annual Reports.
[b] Groundfish data files.

Table 2.2. Lingcod handline/troll and longline catch (t) for Area 4B by statistical area, 1951-89.

	Statistical Area										
Year	12	13	14	15	16	17	18	19	20	28	29	Total
1951	23.3	397.9	88.5	46.3	99.3	357.9	253.2	32.2	17.3	1.8	0.4	1318.1
1952	11.8	440.3	83.6	73.2	169.3	438.0	235.7	28.6	25.2	7.0	0.0	1512.7
1953	5.7	345.8	84.4	46.1	166.2	289.0	179.0	38.9	28.2	4.4	0.1	1187.8
1954	16.0	437.3	157.6	21.5	244.9	362.5	169.1	33.7	13.2	4.8	1.9	1462.5
1955	6.5	330.0	84.4	64.7	243.0	338.9	112.3	44.1	8.0	0.0	0.0	1231.9
1956	17.2	564.7	96.3	60.6	235.0	396.8	106.9	44.1	2.1	1.2	0.8	1512.3
1957	7.0	542.4	82.4	107.2	288.4	364.7	96.9	54.0	2.3	0.3	0.8	1546.4
1958	16.5	497.2	105.6	79.3	229.7	350.2	93.5	73.8	4.5	0.6	0.0	1450.9
1959	16.1	338.3	86.7	31.4	167.8	345.3	85.3	104.7	0.8	0.6	15.4	1192.4
1960	24.3	337.9	110.7	47.1	173.9	378.0	97.0	82.8	23.1	1.3	3.5	1279.6
1961	32.1	393.1	92.1	45.6	183.7	285.7	64.3	63.6	29.6	7.7	2.4	1199.9
1962	160.2	412.0	114.1	60.4	139.0	241.2	57.2	76.4	19.4	8.9	4.1	1293.0
1963	68.0	301.4	63.1	30.5	159.6	250.6	44.7	63.5	20.7	0.1	0.1	1002.3
1964	36.3	289.8	43.3	18.8	170.0	191.5	53.8	52.6	21.4	0.1	0.4	878.0
1965	30.3	303.2	52.4	6.6	135.8	155.3	50.1	39.3	11.2	0.0	4.6	788.8
1966	44.4	299.5	61.7	28.7	125.7	131.4	61.2	33.0	17.6	1.1	0.0	804.3
1967	49.3	332.8	55.7	19.8	133.3	109.6	69.9	17.8	7.0	0.0	0.4	795.6
1968	50.7	273.6	54.2	22.0	104.7	157.7	53.3	14.8	10.5	0.0	0.7	769.2
1969	61.9	227.7	81.9	56.0	109.5	143.5	52.3	31.7	13.8	0.0	0.1	778.4
1970	46.4	225.5	40.8	84.7	85.7	272.1	37.4	23.7	6.5	0.0	0.6	823.4
1971	50.1	119.2	30.0	66.5	89.7	199.9	22.7	18.9	2.2	0.1	0.1	599.4
1972	39.5	152.3	25.1	43.6	81.3	129.9	19.6	38.5	2.4	0.0	0.5	532.7
1973	22.2	85.9	8.4	62.0	38.2	123.7	34.4	27.7	1.1	0.6	0.2	404.4
1974	11.2	129.6	13.3	25.2	23.3	127.6	22.2	16.7	2.9	0.0	0.3	372.3
1975	8.6	93.9	15.1	76.0	26.5	123.0	10.9	8.9	5.0	0.0	0.9	368.8
1976	10.4	96.0	12.9	74.9	17.2	82.5	13.4	9.8	7.8	5.7	0.4	331.0
1977	25.7	128.0	31.4	63.4	19.0	104.1	40.6	15.7	2.6	2.2	0.3	433.0
1978	13.8	158.0	25.3	48.3	18.4	145.3	36.1	42.2	5.7	0.2	2.0	495.3
1979	29.2	215.5	36.8	28.7	15.6	157.4	26.9	30.2	13.7	7.1	1.5	562.6
1980	14.7	131.6	14.2	25.8	6.6	103.3	23.9	23.0	5.3	4.5	0.7	353.3
1981	17.5	137.4	28.9	34.6	12.9	83.6	16.4	16.3	3.3	0.1	0.5	351.5
1982	20.1	177.8	14.9	48.0	7.7	59.6	20.3	17.5	2.1	0.5	1.1	369.6
1983	16.8	112.3	17.9	32.9	13.2	56.5	18.0	14.1	4.6	0.3	0.3	286.9
1984	18.7	65.6	7.0	4.0	5.2	46.5	30.1	13.0	2.5	0.0	0.2	192.8
1985	20.1	46.0	8.2	4.0	0.3	29.8	15.9	10.5	2.6	0.0	0.3	137.7
1986	21.0	20.2	16.0	0.5	2.4	17.2	12.9	13.7	1.8	0.0	0.5	106.2
1987	15.6	22.6	2.2	0.9	0.1	10.0	8.0	8.4	5.9	6.7	0.0	80.4
1988	43.6	12.1	2.5	0.1	0.2	7.1	4.4	8.4	2.4	1.6	1.1	83.5
1989	33.1	7.7	5.0	0.3	0.9	4.6	5.1	12.1	2.6	0.0	0.0	71.4

Source: 1951-1966 British Columbia Catch Statistics, Annual Reports.
1967-89: Sales slip data files.

Table 2.3. Lingcod sport catch (t)[a] for the Strait of Georgia by statistical area from the creel survey (Shardlow et al. 1989, 1990; Shardlow and Collicutt 1989a-e), 1980-89.

Year	Statistical Area									Creel Total
	13	14	15	16	17	18	19	28	29	
1980	41.8	12.6	2.4	22.6	12.6	9.6	13.8	4.6	6.7	126.7
1981	43.4	17.1	8.0	15.4	9.1	12.6	23.0	7.4	9.8	145.8
1982	24.0	9.1	2.1	31.4	14.2	9.6	20.3	9.8	5.9	126.4
1983	25.8	3.7	1.8	32.2	11.4	10.1	15.7	10.9	6.9	118.3
1984	63.5	18.2	2.7	45.9	26.2	11.4	26.4	14.2	13.0	219.8
1985	37.1	9.9	1.4	22.4	14.2	4.5	20.8	5.0	4.3	123.7
1986	41.3	15.5	2.1	15.0	10.1	6.9	17.1	3.0	2.6	113.6
1987	37.6	16.5	2.3	13.0	11.1	4.8	17.5	1.3	1.2	105.3
1988	36.1	18.5	2.1	15.7	9.3	5.6	14.4	1.2	2.7	105.5
1989	33.4	13.8	1.3	11.9	7.6	4.8	9.1	0.5	1.2	83.7

[a] An average weight of 1.6 kg was used to convert numbers to weight.

Table 2.4. Lingcod CPUE (kg/d) by statistical area and for Area 4B combined, lingcod catch (t) by handline/troll and longline for Area 4B, the proportion (Prop) of the catch by these gears that satisfies the qualification criterion, effort (d), and the number of vessels (Vess) that reported a qualified line catch.

Year	CPUE by Statistical Area										CPUE	Catch	Prop	Effort	Vess
	12	13	14	15	16	17	18	19	20	28/29					
1967	53	301	236	314	213	127	124	164	130	87	181.1	795.5	0.86	4313	
1968	37	318	179	375	194	127	110	168	157	227	156.8	742.3	0.89	4734	
1969	57	272	168	438	213	136	129	292	128	-	170.3	767.8	0.89	4509	
1970	50	254	168	351	196	175	154	228	161	257	182.0	823.3	0.90	4524	
1971	83	266	171	267	196	166	113	217	275	25	174.2	599.2	0.89	3440	
1972	50	301	201	283	178	143	150	191	245	147	164.9	523.7	0.85	3176	
1973	40	287	132	264	185	167	150	207	191	119	168.4	404.2	0.91	2401	
1974	36	312	253	269	135	139	135	170	156	327	172.1	370.9	0.90	2155	
1975	23	312	160	242	194	171	189	193	208	46	189.5	368.7	0.94	1966	
1976	38	275	150	250	123	174	126	128	168	140	181.2	331.3	0.89	1825	
1977	52	200	192	256	222	148	125	136	45	115	155.9	433.6	0.76	2781	
1978	74	192	126	206	278	155	105	131	33	210	150.8	501.8	0.88	3327	
1979	76	198	144	270	184	224	116	124	144	163	173.8	561.5	0.85	3231	253
1980	73	274	87	220	92	167	95	101	105	119	159.7	354.1	0.85	2217	205
1981	168	177	90	194	129	148	87	94	77	46	146.1	343.7	0.87	2352	206
1982	66	189	85	152	83	129	130	96	100	55	139.8	370.2	0.86	2648	226
1983	123	138	118	235	127	144	95	93	194	51	138.3	287.3	0.85	2077	174
1984	76	74	80	99	126	95	159	124	100	36	91.6	193.1	0.83	2108	156
1985	74	107	90	104	156	132	71	191	36	96	100.3	137.8	0.70	1374	96
1986	45	53	131	175	119	103	87	114	78	35	73.8	106.2	0.60	1439	83
1987	33	32	44	93	-	84	87	53	141	213	50.4	80.5	0.75	1596	89
1988	37	31	19	-	-	80	84	59	60	96	41.2	83.0	0.74	2015	85
1989	37	44	-	-	-	114	61	56	67	-	48.4	71.4	0.75	1475	86

Table 2.5. Mean length (cm) of lingcod, with sample size (N) and standard error (SE), from biological samples of the commercial handline and sport fisheries by statistical area and sex.

Year	Male			Female			Combined sexes		
	N	Mean	SE	N	Mean	SE	N	Mean	SE
Commercial Fishery - Area 13									
1981	72	71.0	0.7	244	76.0	0.6	316	74.8	0.5
1982	54	71.0	0.7	173	80.7	0.7	227	78.4	0.6
1983	137	70.3	0.5	527	80.2	0.4	667	78.1	0.4
1984	124	66.2	0.6	131	73.8	0.8	255	70.1	0.5
1988-total	93	55.9	0.6	71	61.1	0.9	164	58.2	0.5[a]
1988-kept	43	60.6	0.5	46	65.5	0.7	89	63.1	0.5[a]
Commercial Fishery - Area 17									
1979	70	70.8	0.9	130	81.1	1.0	200	77.5	0.8
1981	360	69.6	0.4	271	81.6	0.8	633	74.5	0.5
1982	90	68.9	0.8	135	81.6	0.8	255	76.5	0.7
1983	591	65.9	0.3	614	73.2	0.4	1207	69.5	0.3
Sport Fishery - Strait of Georgia									
1983	13	53.4	2.0	14	57.2	3.6	27	55.4	2.1
1984	24	59.2	1.8	16	61.7	3.4	41	59.8	1.7
1985	129	53.5	0.7	89	54.5	1.2	219	53.9	0.7
1986	351	53.9	0.5	179	59.1	1.0	545	55.5	0.5
1987	318	55.3	0.6	212	56.8	1.0	543	55.8	0.5
1988	170	55.4	0.8	139	60.3	1.1	320	57.5	0.7
1989	173	56.0	0.7	167	56.7	1.0	359	56.2	0.6
Sport Fishery - Barkley Sound									
1988	59	59.4	9.9	2	64.2	17.5	83	60.1	8.5
1989	220	63.9	0.7	68	69.0	1.7	303	64.5	0.7

[a] Undersize fish (released in compliance with the 58 cm size limit) were also measured.

Table 2.6. Lingcod trawl catch, line catch, total catch, CPUE and effort for Area 3C and Area 3D, 1956-89.

Year	Area 3C					Area 3D				
	Trawl (t)	Line (t)	Total (t)	CPUE (kg/h)	Effort (h)	Trawl (t)	Line (t)	Total (t)	CPUE (kg/h)	Effort (h)
1956	1151	156	1307	292	4398	168	135	303	421	707
1957	1070	295	1365	307	4405	130	146	276	588	470
1958	1047	156	1203	442	2580	109	130	239	723	314
1959	1742	113	1855	408	4266	64	102	166	563	276
1960	1867	219	2086	293	6634	87	115	202	776	244
1961	1972	136	2108	426	4555	200	125	325	591	550
1962	890	228	1118	291	3676	286	112	398	298	1334
1963	609	147	756	462	1608	115	132	247	365	664
1964	1127	101	1228	437	2737	226	92	318	540	578
1965	1812	122	1934	398	4476	505	97	602	404	1457
1966	2030	158	2188	329	6189	585	147	732	607	1177
1967	1779	246	2025	408	4716	459	180	639	566	1098
1968	1661	156	1817	584	2786	868	117	985	681	1400
1969	1054	171	1225	298	3673	619	84	703	306	2053
1970	703	286	989	291	3302	456	171	627	321	1922
1971	979	231	1210	346	3469	264	124	388	246	1548
1972	625	267	892	278	3139	85	197	282	235	1168
1973	876	185	1061	364	2836	172	91	263	411	630
1974	1029	224	1253	240	4933	242	123	365	509	677
1975	1630	216	1846	292	5555	347	97	444	251	1553
1976	1205	253	1458	204	6956	245	98	343	302	1108
1977	844	267	1111	236	4618	158	116	274	293	922
1978	360	91	451	184	2404	197	95	292	458	625
1979	602	82	684	220	3044	147	110	257	316	809
1980	623	97	720	242	2876	127	95	222	199	1074
1981	603	240	843	179	3870	87	122	209	170	1014
1982	1510	221	1731	331	4917	49	175	224	188	1119
1983	970	170	1140	314	3507	447	153	600	299	1944
1984	1731	128	1859	391	4581	322	153	475	204	2241
1985	3416	207	3623	469	7364	380	194	574	478	1199
1986	834	241	1075	325	3127	246	229	475	306	1458
1987	492	234	726	189	3504	88	327	415	288	1317
1988	566	113	679	231	2767	283	235	518	265	1842
1989	839	121	960	283	2989	294	183	476	225	2039

Table 2.7. Lingcod trawl catch, line catch, total catch, CPUE and effort for Area 5A and Area 5B, and Area 5A/B catch, CPUE and effort, 1956-89.

Year	Area 5A				Area 5B				Area 5A/B		
	Trawl (t)	Line (t)	Tot. (t)	CPUE (kg/h)	Trawl (t)	Line (t)	Tot. (t)	CPUE (kg/h)	Total (t)	CPUE (kg/h)	Effort (h)
1956	350	24	374	371	250	4	254	470	628	443	1416
1957	433	1	434	258	170	6	176	295	611	284	2135
1958	296	1	297	139	276	0	276	417	573	353	1613
1959	192	1	193	359	429	1	430	410	623	400	1544
1960	280	13	293	276	377	2	379	373	673	352	1903
1961	388	19	407	534	323	3	326	274	733	366	1964
1962	531	36	567	363	407	5	412	297	979	328	2940
1963	285	27	312	295	357	16	373	259	685	280	2423
1964	352	8	360	342	335	8	343	186	703	305	2272
1965	331	5	336	363	566	8	574	169	910	282	3148
1966	706	24	730	349	826	7	833	362	1563	351	4423
1967	759	22	781	322	901	5	906	477	1687	368	4543
1968	1227	17	1244	296	1043	11	1054	400	2298	302	7214
1969	617	28	645	139	517	9	526	233	1170	156	7290
1970	590	29	619	250	390	16	406	255	1026	248	4093
1971	230	27	257	141	415	14	429	174	685	156	4351
1972	164	47	211	197	476	27	503	157	714	173	4119
1973	232	38	270	178	349	20	369	131	639	173	3689
1974	339	40	379	203	532	31	563	205	942	202	4637
1975	82	31	113	112	451	23	474	203	587	161	3629
1976	258	42	300	244	345	28	373	174	673	194	3467
1977	122	50	172	117	257	18	275	195	446	157	2838
1978	128	20	148	224	162	12	174	168	322	189	1692
1979	100	32	132	186	242	12	254	179	386	167	2137
1980	108	33	141	103	302	12	314	174	455	137	2842
1981	183	33	216	227	548	12	560	237	776	216	3304
1982	468	35	503	249	580	9	589	239	1091	236	4492
1983	573	37	610	267	772	10	782	337	1392	307	4501
1984	261	47	308	190	455	10	465	198	773	187	3966
1985	408	45	453	255	469	23	492	236	944	227	3874
1986	640	41	681	346	1012	7	1019	403	1700	367	4468
1987	676	99	775	267	756	10	766	308	1541	280	5398
1988	554	98	652	284	737	23	760	344	1412	300	4448
1989	879	124	1003	290	737	19	756	327	1759	281	5748

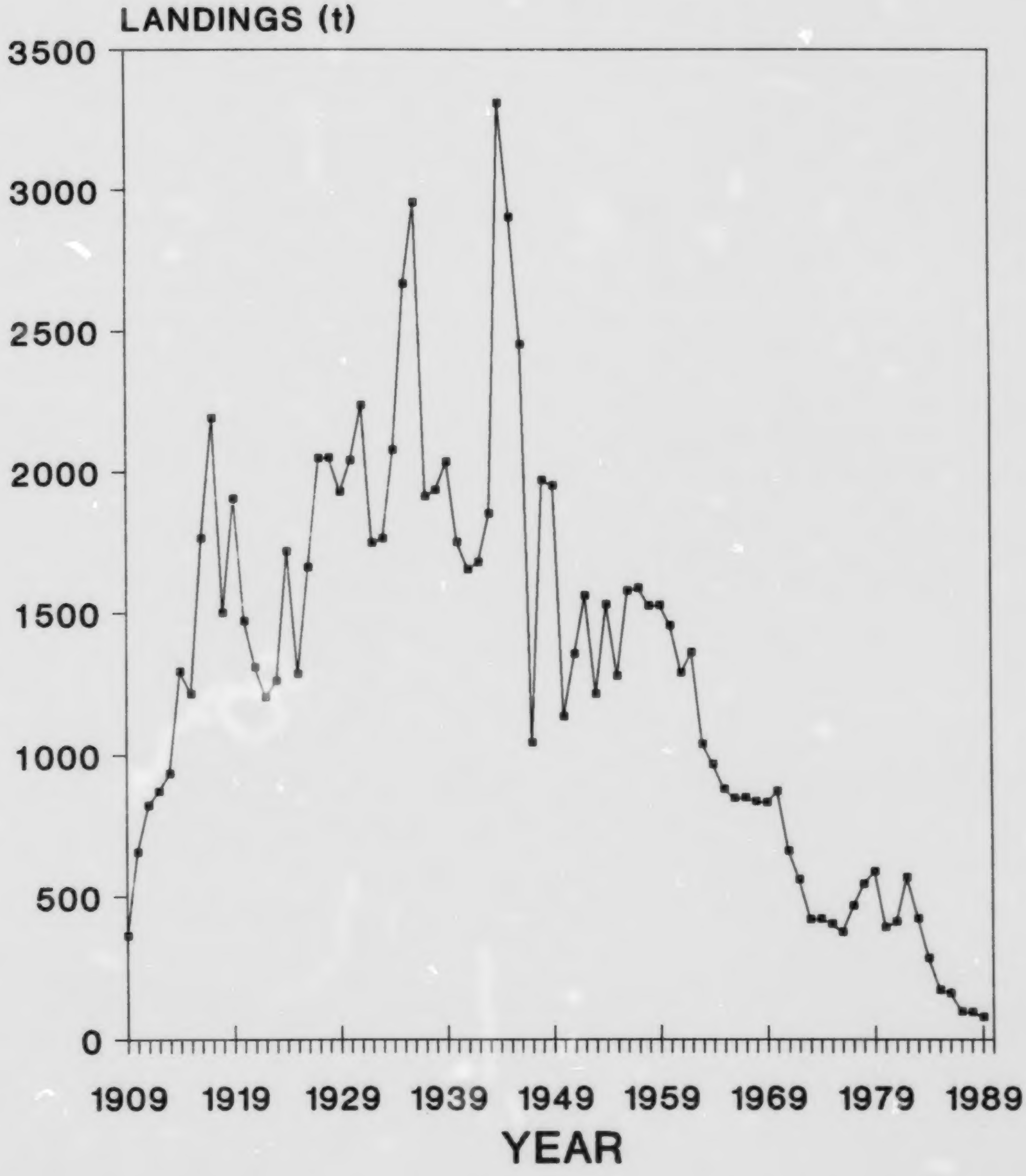


Fig. 2.1. All-gear commercial lingcod catch from Area 4B, 1909-89.

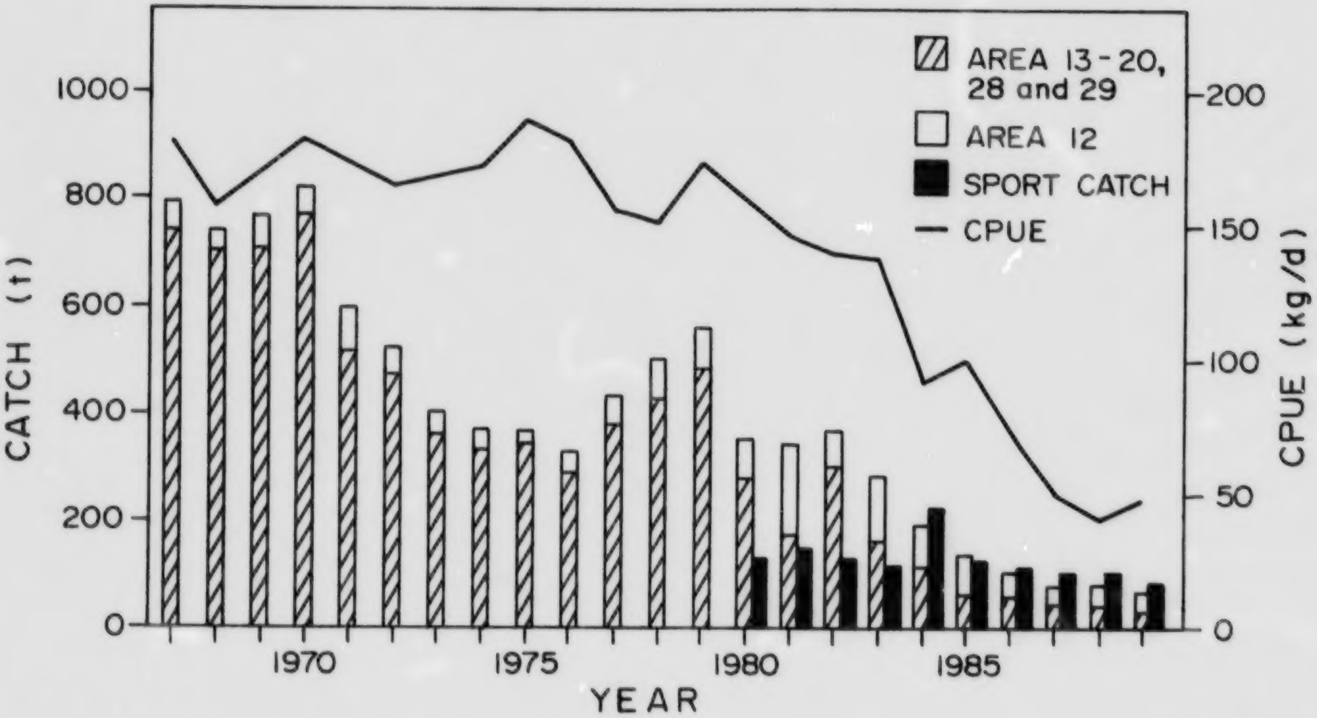
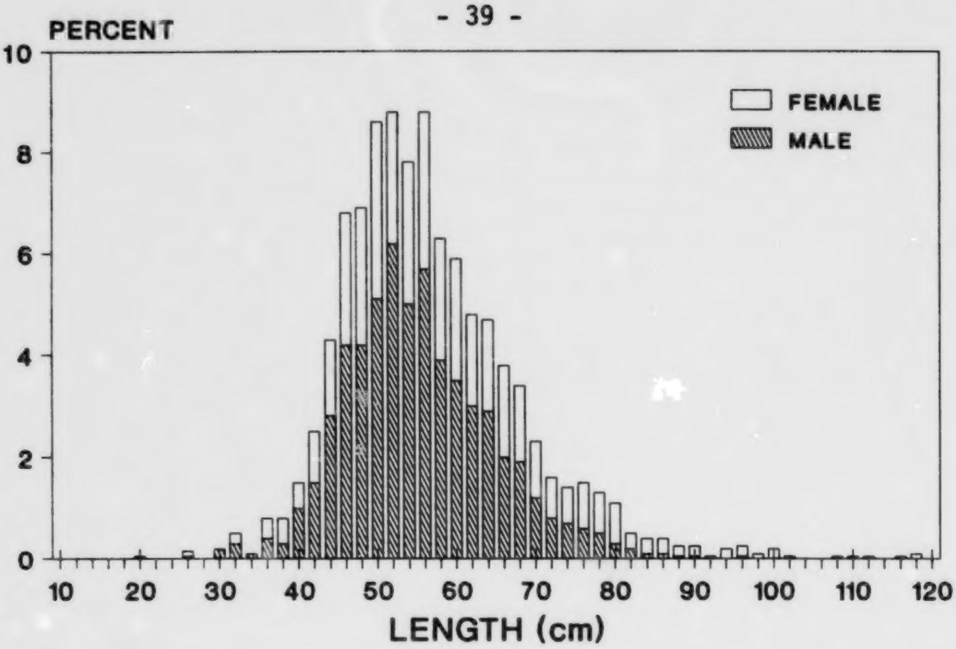


Fig. 2.2. Lingcod commercial handline/troll and longline catch from areas 13-20, 28 and 29 (t, hatched bars) and area 12 (t, stacked open bars), sport fishery catch from areas 13-20, 28, and 29 (t, solid bars) and commercial CPUE (kg/d, line), 1967-89.



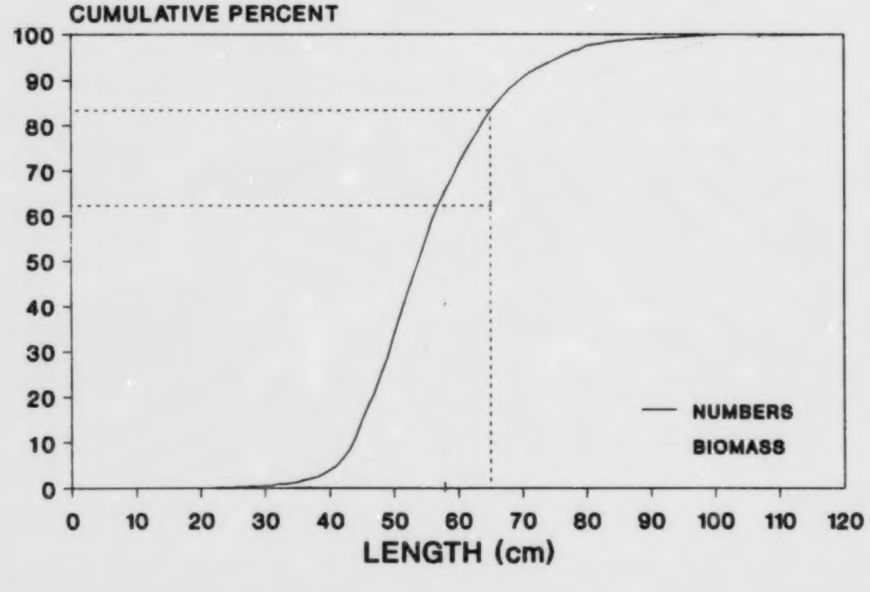
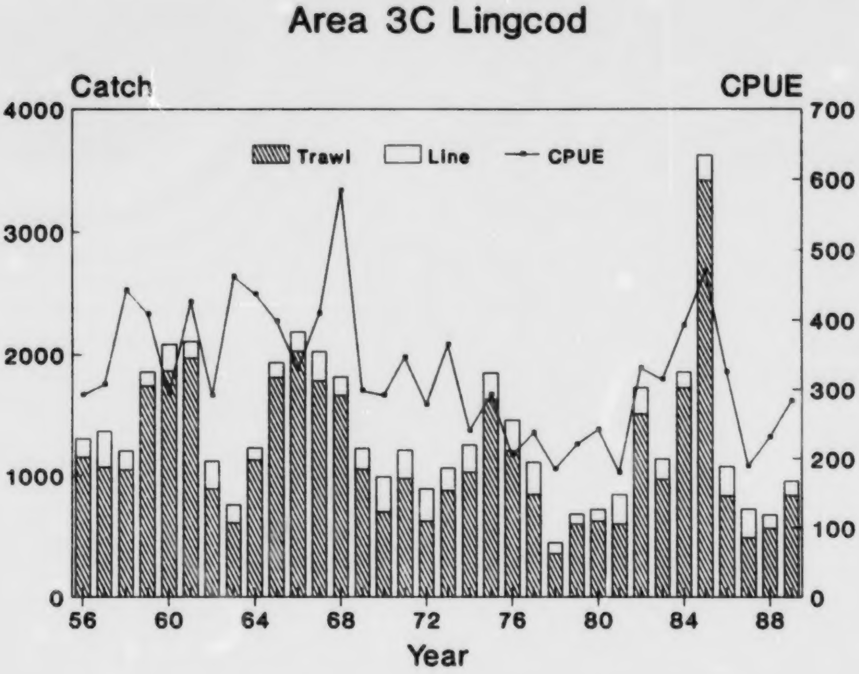


Fig. 2.3. Length-frequency distribution of lingcod caught in the sport fishery, 1983-89 (N=1692) (top panel) and the corresponding cumulative length-frequency distributions by number and biomass (bottom panel). The dotted lines indicate the proportions of the catch by number and biomass less than the commercial size limit of 58 cm. The dashed lines indicate the corresponding proportions for a 65 cm size limit.



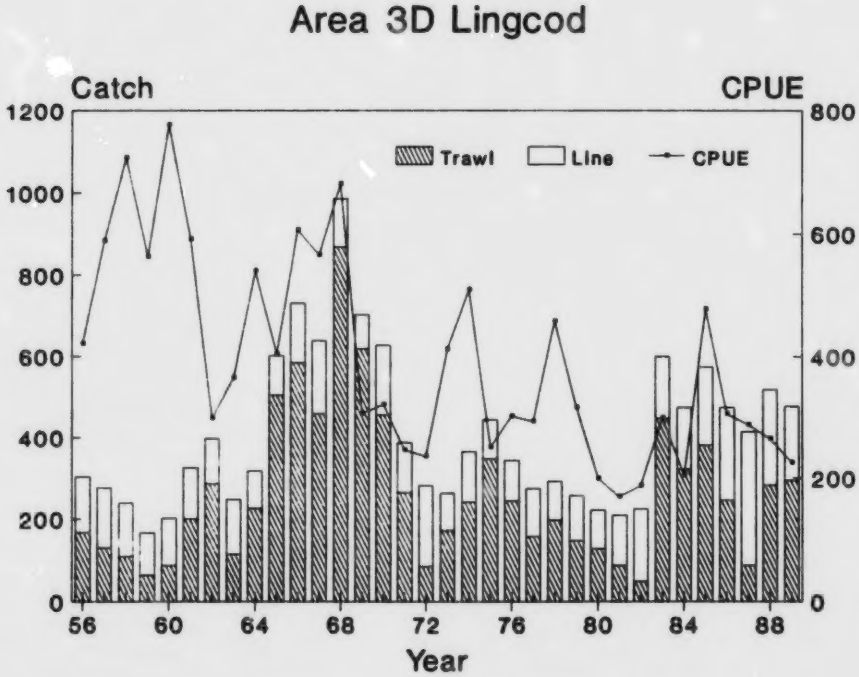


Fig. 2.4. Lingcod trawl catch (t, hatched bars), line catch (t, stacked open bars), and trawl CPUE (kg/h, line) for Area 3C and Area 3D, 1956-89.

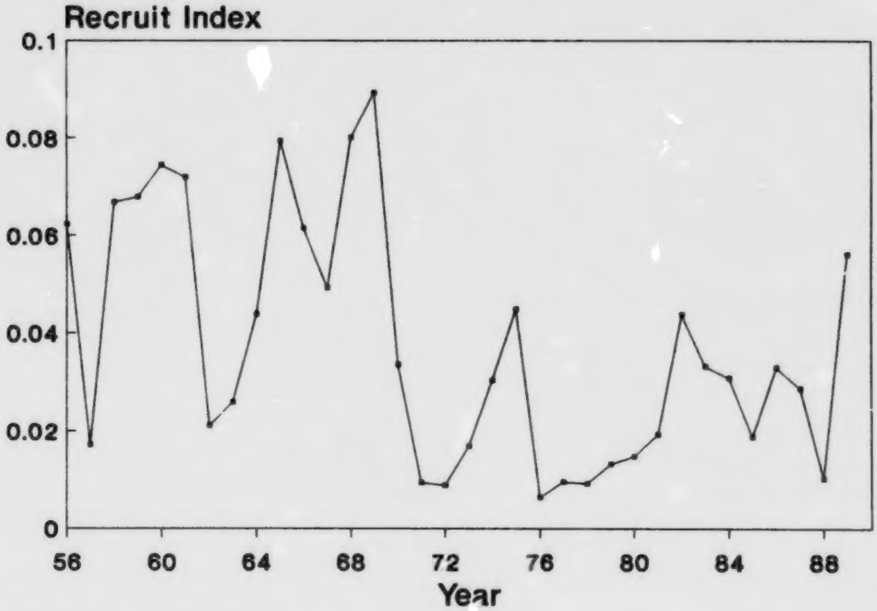


Fig. 2.5. Recruit index (t/h) determined from the product of CPUE and the proportion of new recruits in the catch. New recruits are defined as fish in the size range of 2.25 to 2.88 kg, based on Schnute et al. (1989a).

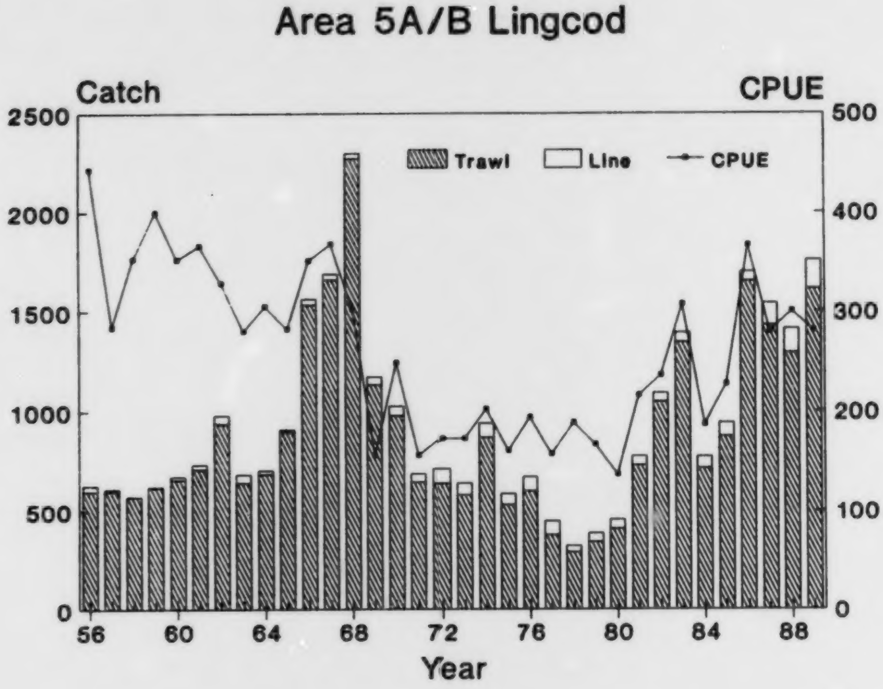


Fig. 2.6. Lingcod trawl catch (t, hatched bars), line catch (t, stacked open bars), and trawl CPUE (kg/h, line) for Area 5A/B, 1956-89.

3.0. PACIFIC COD

by R. P. Foucher and A. V. Tyler

3.0.1. General Introduction

Pacific cod (Gadus macrocephalus) continues to be a major component of the domestic, on-bottom trawl fishery. The 9,174 t of Pacific cod landed in 1989 was exceeded only by the landings of Pacific hake. In Canadian waters, Pacific cod is close to the southern limit of its commercial abundance and exhibits rapid growth and a short life span. Recruitment begins at age 2, while most are recruited and mature by age 3. Few survive to age 7. Year-class strength varies considerably resulting in a wide variation in annual landings (Figure 3.1).

Among regions, cod production is greatest in the most northerly Canadian stock, Hecate Strait, and negligible off the west coast of the Queen Charlotte Islands.

3.1. Coastwide

Pacific cod were not treated as a coastwide stock.

3.2. Georgia Strait and vicinity (Area 4B)

3.2.1. Introduction

No new analyses have been conducted since a detailed stock assessment was carried out in 1986 (Westrheim and Foucher 1987). Nominal catch (landings) during 1989 was 602 t, a decrease of 51% from 1988 (Table 3.1). This decrease in landings and the decrease in CPUE from 406 to 265 kg/h are probably both due to the strong 1985 year-class passing out of the fishery.

3.2.2. Landing Statistics

Landings were compiled and reported by calendar year. Equivalent effort was calculated by dividing the landings by the nominal CPUE. For each year, the CPUE was calculated over a period including the previous fourth quarter and the first quarter of the year in question. Interviewed landings were divided by interviewed effort. These were selected using a 40% qualification level as described in Westrheim and Foucher (1987). This was done to avoid splitting the main period of the fishery (October-March) between two years. Also, fish present during the fishery in these quarters give an indication of the parent stock that will produce the new year-class.

By minor Statistical Area, landings decreased in all areas including Area 19 (Victoria) which decreased by almost 500 t.

3.2.3. Yield Options

Regulation does not appear to be necessary at this time. There are no symptoms of overfishing and current minimum mesh-size is reasonably satisfactory with respect to optimizing catch (Westrheim and Foucher 1987).

3.3. West Coast of Vancouver Island (Areas 3C and 3D)

3.3.1. Introduction

Pacific cod is the principal shelf species sought by the on-bottom trawl fishery off the west coast of Vancouver Island. Area 3C produces approximately 90%, and Area 3D, 10% of the total nominal catch (landings) for the two areas combined. Within Area 3C, principal trawling grounds are Amphitrite Bank (53% of Area 3C landings), Big Bank (28%), and Swiftsure Bank (14%) (Foucher and Westrheim 1984). Amphitrite Bank is a major spawning ground for cod, and 77% of its production historically (prior to 1980) occurs during January-March. Big Bank and Swiftsure Bank are feeding areas for cod, with most catch occurring primarily during April-September -- 79% and 89%, respectively. The trawl fishery on spawning cod began about 1961, assumed considerable importance after 1971, and has been subject to various conservation regulations since 1977, most recently (1988) closures during the months of January, February and March on the spawning grounds. Only the first 14 days of each month were open during this period.

3.3.2. Landing Statistics

Landing statistics are based on Foucher (1987) for detailed records by ground. Effort was allotted to the mixed-species fishery using the method of Westrheim (1983), and standardized according to the method of Westrheim and Foucher (1985a). Briefly, the standardization was a linear function utilizing vessel horsepower as the single factor in the regression. Representative nominal CPUEs for the region were derived from Canadian records for Big Bank, April-September. Landings, effort and CPUE have all fluctuated substantially (Table 3.2; Figure 3.2). Landings for Areas 3C and 3D to June 30, 1990 were 1523 t compared to 2569 t for the same period in 1989.

3.3.3. Age Composition

Age compositions are derived from length frequencies for Canadian cod landings using the method of Foucher and Fournier (1982). Age-classes 2-4 predominate in the landings, and few cod landed from the west coast of Vancouver Island are older than age 7 (Table 3.2). Recruitment is considered complete at age 3 under present fishery conditions. Year-class abundance during 1962-86, based on CPUE at age 2, fluctuates substantially --0.8 cod/h in 1985 to 124.2 cod/h in 1971. Data prior to 1962 are questionable due to the dissimilarity of the Canadian and U.S. trawl fleets at that time, and the absence of detailed records of the catches by U.S. vessels. Possible problems with accurately determining the proportions of older groups were pointed out by Westrheim and Foucher 1985b.

We plotted the length-frequency distributions of 3C cod for the second quarter of the year for the past four years (1987-90) in order to look at the relative abundance of the recruiting age-2 and age-3 fish (Figure 3.3). The 1990 sample was from February rather than from the second quarter as there were no second quarter samples. The strong 1985 year-class first showed up as a prominent mode at about 45 cm in 1987 and could be followed through to 1990 when, at age 5, they produced a prominent mode at about 70 cm. There has been no evidence since 1987 of any strong recruitment.

3.3.4 Mortality Rates

The derivation of mortality rates previously described (Foucher and Tyler 1988), resulted in best estimates for this area of:

Instantaneous fishing mortality rate	0.50
Instantaneous natural mortality rate	0.69
Instantaneous total mortality rate	1.19

The natural mortality rate was rounded to 0.7 for the following analyses. The age determination process is still under study. A comparison of age compositions derived by the length-frequency method, which was used to produce the time-series of ages used, and the fin-ray method is in progress.

3.3.5 Virtual Population Analysis

A virtual population analysis (Gulland 1983) was undertaken using catch-at-age determined from the age composition and catch statistics (Table 3.3). It utilized the mortality rates estimated for ages 4-5; terminal F at age 7 = 0.5; M = 0.7 for all ages. Terminal F was allowed to vary around 0.50 by first calculating an overall q:

$$q = F / E, \quad \text{where } E = \text{mean effort}$$

and then calculating terminal F for each year:

$$F = q * E, \quad \text{where } E \text{ is the effort for that year.}$$

This allowed the terminal F value to vary with effort which is more realistic than holding it constant for all years. Estimated numbers present (for age-classes represented by ages 2-7 -- 1954-79) at age 2 ranged from 0.8 million in 1982 to 9.1 million in 1971 (Table 3.4). Mean values of F by age-class were 0.08, 0.32, 0.53, 0.64, 0.69, and 0.50 for ages 2-7, respectively

(Table 3.5). Mean exploitation rates for the time series were 0.05, 0.19, 0.29, 0.33, 0.34, and 0.28 for ages 2-7, respectively (Table 3.6).

3.3.6. Condition of the Stock

The beginning of a fishery concentrating on spawning cod on Amphitrite Bank coincided with the start of a relatively steady decline in abundance after the early 1970s. In response to this heavy fishing pressure, a predictor was developed to forecast the probable January-March landings from Area 3C. This was based on the landings from the previous second and third quarters (Ketchen 1980).

Later, Big Bank, April-September, was chosen as the representative area-time cell from which to calculate CPUE for Area 3C as a whole (Foucher and Westrheim 1984), and this has subsequently been used as an abundance index for the Area 3C stock.

The index changed little from 1988 (200 kg/h) to 1989 (197 kg/h). Preliminary data for 1990 indicate that catch rates have declined further. CPUE for April-June 1990 is 147 kg/h which equals the historic (1956-89) mean level for quarters 2 and 3. The final CPUE value for the stock will include the period April-September inclusive and may be even lower as quarter 3 CPUE has historically been only 71% of the CPUE for quarter 2.

There was no closure during 1989 or 1990. In the previous assessment (Tyler and Foucher 1990) the history of closures was reviewed. It was there noted that "due to the short life-span of a cod year-class in the fishery, regulations to limit catch may have to be imposed again in the future." In view of the current downturn in CPUE, caution is necessary. The length-frequency distribution in early 1991 will be examined to assess the strength of the 1989 year class and the results of this will help to determine whether future action will be necessary.

On the basis of the current average condition of the stock and the current moderate levels of fishing effort, it would seem reasonable to keep the area open for a winter fishery.

3.3.7 Yield options

With the stock now at average levels of CPUE, the fishery could remain open for the first quarter but with the caution that if above average new recruitment is not observed at that time, action may subsequently be required to, once again, limit the fishery in 1992.

3.4. Queen Charlotte Sound (Areas 5A and 5B)

3.4.1. Landing Statistics

Nominal catch (landings) in 1989 was 762 t from 5A and 5B combined (Table 3.7), a decrease of 59% from 1988 landings. They are now more than 40% less than the average annual landing level from Queen Charlotte Sound whereas last year they were more than 40% more. This decline, as in the other regions, is probably due to the phasing out of the 1985 year-class from the fishery. Landings in 1990 are continuing to decrease from these high levels. In 1990, January-June landings were 323 t compared to 384 t in 1989.

3.4.2. Condition of the Stock

The 1984 assessment (Westrheim and Foucher 1985b) indicated that there was little danger of overfishing because of extensive, rough-bottom refuges from trawling. However, the dramatic drop in landings from 1987 levels indicates that the very high catch levels may have harvested much of the 1985 year-class during their first three years in the fishery.

3.4.3. Yield options

No recommendation is made for the fishery in Queen Charlotte Sound. Overfishing by the trawl fishery in 5A/5B is considered unlikely due to the extent of untrawlable bottom at depths frequented by Pacific cod.

3.5. Hecate Strait (Areas 5C and 5D)

3.5.1. Introduction

The stock of Pacific cod in Hecate Strait is the largest off the west coast of Canada. During 1987, when the coastwide cod catch was higher than in any years of the previous decades (and since), 8870 t came from Hecate Strait out of 13940 t for the entire coast (rounded figures), i.e., 64%. As with other Canadian Pacific cod stocks, recruitment and subsequently total biomass, fluctuates widely from natural causes (Tyler and Westrheim. 1986), exhibiting 199% shifts in biomass since 1970 (8825 t in 1982 and 17576 t in 1974, based on VPA).

3.5.2. The Fishery

Nominal catch from Hecate Strait is divided between two major areas and several important grounds (Figure 3.4). Nominal catch from the northern area (5D) was 3872 t in 1988, and 3033 t in 1989. Catch from the southern area of the Strait (5C) was 2326 t in 1988 and 1754 t in 1989. Market conditions continued to be average to poor in 1989, as they were in 1988 (personal communications, Groundfish Advisory Committee).

3.5.3. Landing Statistics

Effort (Table 3.8; Figure 3.5) was fairly constant up to the mid-1960s, after which there were a series of irregular fluctuations, likely in response to strong year-classes. Effort tended to increase following strong recruitment, then decrease with a lag one or two years after catch and nominal CPUE fell off. Since 1986, effort has been increasing annually. Nominal CPUE also fluctuated but not synchronously with landings. The increases in landings and CPUE associated with the strong 1985 year-class have now been reversed. Landings to June 30, 1990 were 2687 t compared to 4361 t for the same period in 1989. The mean for landings for Jan 1-Jun 30 over 1956-87 is 2394 t.

3.5.4. Age Composition

Annual age composition in numbers landed per hour trawled (Table 3.9) shows that ages 2-4 are most important to the fishery. Recruitment of age-2 fish begins, historically, in the spring, but, more recently, in the winter. In recent years, recruitment is complete by age 3, but in the past by age 4. Strong year-classes, based on CPUE at age 2 (>100/h), were 1960-62, 1965, 1970-72, 1977 and 1985, which, by this measure, was the strongest year-class observed in this time-series.

We plotted the length-frequency distributions of the combined cod samples of 5C and 5D, for the first quarter of the year, for each of 1987-90 to look at the relative abundance of the recruiting age-2 and age-3 fish (Figure 3.6). We used the first quarter in this case because, in Hecate Strait, there was a substantial fishery during this quarter; 58% of the landings of 1989 and 44% in 1988 were from this quarter.

The 1987 length frequency showed an enormous influx of age-2 fish from the 1985 year-class. This year-class dominated the catch during 1988 and 1989 despite the large catches in 1987. In 1990 they were still present in the commercial fishery as age-5 fish of around 70 cm. A research cruise early in 1989 (Foucher et al. 1989) did not detect many age-1 cod. Another cruise in May-June 1989 (Antonsen et al. 1990) found more age-1 cod, indicating a below average 1988 year-class and that there would be a low to moderate show of age-2 cod in the 1990 commercial sample as in fact occurred (Figure 3.6d). In the first quarter of 1990, unsorted commercial samples collected by an observer (Figure 3.7) and reports from the fishery suggest a good showing of age-1 fish. This indicates that the 1989 year-class may be larger than average. In addition, Groundfish Research port samplers reported that trawler captains had to make regular discards of "roughly one-foot-long" Pacific cod through 1989, an event that occurred in the past only when an exceptionally large year class of age-one fish was present.

By the second quarter of 1991, the largest of these fish will be greater than 18 inches (46 cm) and acceptable to present industry product standards. However, because they will tend to form concentrated aggregations during the winter months, the fish of this year-class will be particularly vulnerable to trawling, and many will be dumped during the normal high-grading process. By next winter their increased body size will prevent any of them from escaping through the trawl mesh. Processors could help the situation by accepting 16-inch (40-cm) fish for the winter months in 1990-91.

3.5.5. Mortality Rates

The method of calculation of mortality rates was reported in Foucher and Tyler 1988. The best estimate of the parameters was considered to be those for ages 4-5: $M = 0.61$ and $F = 0.52$. These were rounded to $M = 0.6$ and $F = 0.5$ for the following analysis.

3.5.6. Virtual Population Analysis

Virtual population analysis was carried out as described in Section 3.3.5 using catch at age determined from age composition and landing statistics (Table 3.9). The VPA estimates of numbers of cod at age-2 ranged from 2.7 million in 1982 to 16.0 million in 1987 (Table 3.10). Mean values of F by age-class were 0.14, 0.37, 0.57, 0.61, 0.61 and 0.70 for ages 2-7, respectively (Table 3.11). Mean exploitation rates were 0.09, 0.23, 0.32, 0.34, 0.33, and 0.29 for ages 2-7, respectively (Table 3.12).

3.5.7. Condition of the Stock

The abundance index for Pacific cod in Hecate Strait, calculated from the CPUE from Horseshoe and Two Peaks-Butterworth during April-September (Table 3.8) indicated a decrease in abundance. The index decreased from 651 kg/h in 1988 to 459 kg/h in 1989. Data for 1990 indicated a further decline to 397 kg/h (based on April-June only). A correlation of CPUE for quarters 2 and 3 combined on CPUE for quarter 2 (1961-89) gives the following relationship:

$$\text{Q23 CPUE} = 61.8 + 0.997 \text{ Q2 CPUE}; \quad r = 0.93$$

A quarter-2 CPUE of 413 kg/h would be predicted, from this relationship, to lead to an overall CPUE (quarters 2 and 3) of 474 kg/h. Even at that level, stock size, as measured by CPUE, would be 32% below the mean of 699 kg/h for the period 1962-81. We took the mean of this 20-year period to be a bench mark figure because effort data were improved in quality since 1962, and because the series included three upward and three downward stock swings.

3.5.8 Simulation analysis

A simulation analysis described in the last assessment document (Tyler and Foucher 1990) and based on the age-structured, Self-Generating Model described by Tyler and Gallucci (1980) was again used.

Our stock size estimates (text table below) indicate that spawning biomass at the start of 1991 will be adequate to provide good recruitment in response to good conditions of non-tidal water transport and forage, since spawning biomass at year end is approximately at the critical level (4000 t plus or minus 1000 t from the Hecate Strait cod simulation model Tyler and Foucher 1990). If fishing effort stays about the same as in 1989 and 1990, overfishing will not occur and the spawning stock at the end of the year will be within the acceptable range. Our estimate is 3152 t for the year-end spawning biomass. About one third of next year's catch will be from the 1989 year-class.

Year	Ending Total biomass (t)	Ending Spawning biomass (t)	Potential yield (t)	Estimated yield (t)
1990	8088	4029	3248	3514
1991	8676	3152	2777	3488

This catch was estimated on the basis that trawling effort (h) will be the same in both 1990 and 1991.

3.5.9. Yield options

Though we suggest that an annual quota is unnecessary at this time due to a strong 1989 year-class combined with moderate amounts of fishing effort, the following catch limitations would insure that the spawning stock is not over fished:

Low-risk sustainable: 1800 t
Sustainable level: 2800 t
High-risk sustainable: 3800 t

Specifically, the sustainable catch level of 2800 t will ensure that there is a spawning biomass within the range of the critical spawning biomass: 4000 t plus/minus 1000 t for the spawning in February-March, 1992. For a discussion of the estimate of the critical spawning biomass, see Tyler and Foucher, 1990.

Table 3.1. Canadian annual nominal catch (landings), standardized equivalent effort and nominal CPUE for Pacific cod from the Strait of Georgia and vicinity (Area 4B), 1955-89.

Year	Landings (t)	Effort (h)	Nominal CPUE (kg/h)
1955	967	4150	233
1956	578	2580	224
1957	607	2115	287
1958	650	2539	256
1959	1047	3388	309
1960	744	3179	234
1961	415	2015	206
1962	479	3013	159
1963	677	3454	196
1964	713	5204	137
1965	484	2508	193
1966	297	2250	132
1967	475	1331	357
1968	349	2748	127
1969	388	3404	114
1970	502	3118	161
1971	740	2972	249
1972	630	2165	291
1973	441	2250	196
1974	681	2308	295
1975	991	4464	222
1976	927	3911	237
1977	1148	4000	287
1978	1373	5029	273
1979	1197	3706	323
1980	1606	7470	215
1981	1742	6500	268
1982	1011	3703	273
1983	907	4104	221
1984	652	3047	214
1985	463	1508	307
1986	803	2974	270
1987	1015	2934	346
1988	1223	3012	406
1989	602	2272	265

Table 3.2. Canada-U.S.[a] annual nominal catch (landings), standardized equivalent effort, overall nominal CPUE and number/h, by age, for Pacific cod, from the west coast of Vancouver Island (Areas 3C+3D), 1956-89.

Year	C-US Land (t)	C-US Eff (h)	C-US CPUE (kg/h)	Age									
				1	2	3	4	5	6	7	8	9	10
1956	1468	9118	161	-	8.5	20.9	19.6	8.9	0.8	0.6	0.3	-	-
1957	1814	14992	121	-	14.8	17.3	9.2	5.4	1.3	0.2	0.1	0.1	-
1958	850	7727	110	-	1.7	34.4	6.3	2.7	0.5	0.2	-	-	-
1959	907	20156	45	-	1.3	6.4	5.5	1.3	0.1	0.1	-	-	-
1960	635	10583	60	-	0.4	13.0	6.9	2.1	0.4	-	-	-	-
1961	420	23333	18	-	0.4	1.4	3.3	1.4	0.1	0.1	-	-	-
1962	633	18086	35	-	12.4	3.2	2.0	0.8	0.2	-	-	-	-
1963	1231	10894	113	-	30.4	15.7	6.5	1.4	0.2	0.2	-	-	-
1964	1221	3499	349	-	23.6	48.8	39.6	19.4	7.4	0.9	0.5	-	-
1965	2768	13244	209	-	14.4	44.4	19.2	5.1	1.6	0.4	0.1	-	-
1966	3136	12800	245	-	16.6	50.9	24.2	6.4	2.3	0.5	-	-	-
1967	1941	25880	75	-	2.1	16.2	7.6	1.2	0.9	0.1	0.1	-	-
1968	1425	19521	73	-	3.3	13.4	6.0	2.5	0.9	0.3	-	-	-
1969	1092	16059	68	-	4.9	12.1	5.2	2.3	1.1	0.4	0.2	-	-
1970	1095	7821	140	-	29.1	19.3	13.1	3.6	0.7	0.2	0.1	-	-
1971	3328	6710	496	1.3	124.2	85.0	17.7	5.7	1.6	0.9	0.4	-	-
1972	5629	10846	519	0.9	113.3	86.8	27.6	7.6	1.4	0.7	0.4	-	-
1973	3712	17427	213	-	9.7	35.8	19.5	6.4	2.3	0.4	0.1	-	-
1974	3474	18094	192	-	27.2	13.0	23.2	8.9	2.4	0.9	0.4	0.1	-
1975	4000	24845	161	-	13.8	36.2	9.2	4.3	2.1	0.3	0.2	-	-
1976	3797	21212	179	-	8.5	35.6	21.3	5.6	0.7	0.3	0.2	-	-
1977	2948	20331	145	-	11.5	20.8	15.9	5.3	1.8	0.5	0.2	-	-
1978	1998	11964	167	0.1	7.3	34.6	15.4	6.3	0.9	1.2	0.1	0.1	-
1979	1861	8459	220	0.1	26.2	32.7	19.5	8.7	1.5	0.6	0.2	0.1	-
1980	1152	9290	124	0.6	22.3	14.3	10.6	5.1	2.0	0.1	-	0.1	-
1981	918	15300	60	0.3	4.8	19.4	2.7	0.6	0.6	0.3	-	-	-
1982	1123	32086	35	-	2.7	6.6	3.7	1.2	0.4	0.2	-	-	-
1983	694	10515	66	-	16.3	7.2	8.6	1.9	1.3	0.1	-	-	-
1984	675	20455	33	-	4.1	6.8	3.2	1.3	0.2	0.1	-	-	-
1985	493	37923	13	-	0.8	4.6	0.8	0.1	-	-	-	-	-
1986	498	13459	37	-	2.1	4.7	6.3	1.2	0.2	-	-	-	-
1987	810	6429	126	-	63.8	6.3	7.4	6.0	0.6	-	-	-	-
1988	1807	9035	200	-	16.5	54.3	18.3	1.9	1.2	0.8	-	0.2	-
1989	3015	15305	197	0.1	4.5	19.8	25.6	11.8	1.2	-	0.2	-	-

[a] No U.S. landings after March 31, 1981.

Table 3.3. Canada-U.S. landings (numbers), by age, for Pacific cod from the west coast of Vancouver Island (Areas 3C+3D), 1956-89.

	Age									
Year	1	2	3	4	5	6	7	8	9	10
1956	0	77812	190403	179106	80851	7603	5079	2868	0	253
1957	0	221243	259322	138344	80229	19570	3385	1837	894	0
1958	0	13435	265782	48561	20878	4209	1716	0	0	0
1959	0	27078	129177	111650	25259	2628	1802	0	144	323
1960	0	4316	137963	72910	21719	4319	127	0	0	0
1961	0	10498	32892	75962	33410	2691	1473	0	0	0
1962	0	225073	57173	35783	14102	3631	684	0	0	0
1963	0	331033	170554	70558	14818	2030	1904	0	0	0
1964	0	82410	170648	138709	67810	25761	3288	1682	77	0
1965	0	190484	587622	254031	67752	21621	5154	845	0	0
1966	0	212198	651704	310288	82328	29719	5776	348	0	392
1967	0	53829	418220	195833	32250	24079	3406	1728	0	38
1968	0	64683	260813	117080	49369	17369	6183	961	0	0
1969	0	79220	193685	83977	36903	17503	6677	2860	0	0
1970	101	227578	151163	102714	27787	5344	1861	574	0	0
1971	8987	833163	570063	119045	37960	10986	5942	2608	0	0
1972	10125	1229297	941657	299752	81894	14965	7742	3797	0	0
1973	362	168424	623021	339635	111015	39350	6160	2533	0	106
1974	0	492544	235873	420559	160426	42841	16205	6857	1030	0
1975	0	342304	900028	228561	107923	52964	8252	4935	483	0
1976	0	179596	754280	452304	118269	15407	6752	4817	415	0
1977	0	232904	423418	323814	106942	36269	9950	3880	0	0
1978	734	87555	413817	183794	75764	10730	13986	1574	1678	0
1979	954	221260	276858	165238	73645	12421	5353	1938	656	0
1980	5826	206903	133125	98834	47345	18603	1084	191	476	0
1981	4030	73544	296233	40691	8675	9860	5060	0	0	0
1982	256	87087	211167	120000	39972	12198	6160	1544	1032	0
1983	0	171565	75522	90822	19857	13774	810	385	0	0
1984	340	84577	139351	65987	26387	3166	1687	44	0	0
1985	654	31234	174493	31182	5430	993	102	417	0	0
1986	472	27739	62909	85111	16005	2605	195	418	0	0
1987	141	410220	40631	47298	38631	4090	73	24	0	0
1988	0	149326	490324	164897	17054	11061	7119	296	2002	0
1989	1285	68259	303662	391699	180432	17787	507	2560	0	0

Table 3.4. Virtual population analysis estimates of numbers-at-age (thousands) of Pacific cod from the west coast of Vancouver Island (Areas 3C and 3D), for age-classes 2-7, 1956-89.

	Age					
Year	2	3	4	5	6	7
1956	1568	766	513	203	34	27
1957	1987	725	252	135	47	12
1958	1515	836	187	36	16	11
1959	2458	742	237	60	5	5
1960	1701	1204	280	44	13	1
1961	2567	839	503	90	8	4
1962	3189	1266	393	197	22	2
1963	4343	1433	589	171	88	9
1964	4868	1937	593	244	75	42
1965	4420	2365	840	201	76	20
1966	3997	2057	778	246	55	23
1967	3019	1845	585	182	68	8
1968	2591	1465	634	160	68	18
1969	4618	1241	548	236	46	22
1970	6348	2239	484	214	91	11
1971	9147	2997	1006	170	87	42
1972	8137	3961	1098	417	59	36
1973	6246	3196	1326	344	152	19
1974	8044	2992	1164	429	97	49
1975	5518	3665	1324	299	106	20
1976	4203	2514	1206	501	77	18
1977	3504	1970	742	297	169	28
1978	1895	1575	689	156	76	59
1979	1800	882	506	220	28	30
1980	1990	740	252	141	60	6
1981	1486	850	276	59	39	17
1982	809	687	224	109	24	12
1983	2322	342	199	34	27	4
1984	1772	1038	118	39	4	5
1985	1450	825	422	16	3	0
1986	5262	700	290	189	4	1
1987	7186	2596	304	87	83	1
1988	3235	3274	1262	119	18	38
1989	1291	1506	1288	512	48	2

Table 3.5. Virtual population analysis estimates of fishing mortality rate (F) for Pacific cod from the west coast of Vancouver Island (Areas 3C and 3D), age-classes 2-7, 1956-89.

	Age					
Year	2	3	4	5	6	7
1956	0.07	0.41	0.64	0.75	0.36	0.30
1957	0.17	0.65	1.24	1.44	0.80	0.49
1958	0.01	0.56	0.43	1.37	0.45	0.25
1959	0.01	0.27	0.98	0.81	1.34	0.65
1960	0.01	0.17	0.44	1.04	0.58	0.34
1961	0.01	0.06	0.23	0.69	0.62	0.76
1962	0.10	0.06	0.14	0.11	0.25	0.59
1963	0.11	0.18	0.18	0.13	0.04	0.35
1964	0.02	0.14	0.38	0.47	0.62	0.11
1965	0.06	0.41	0.53	0.60	0.49	0.43
1966	0.07	0.56	0.75	0.59	1.23	0.42
1967	0.02	0.37	0.59	0.28	0.64	0.84
1968	0.04	0.28	0.29	0.54	0.42	0.63
1969	0.02	0.24	0.24	0.25	0.71	0.52
1970	0.05	0.10	0.35	0.20	0.09	0.25
1971	0.14	0.30	0.18	0.36	0.19	0.22
1972	0.23	0.39	0.46	0.31	0.42	0.35
1973	0.04	0.31	0.43	0.57	0.43	0.57
1974	0.09	0.12	0.66	0.70	0.88	0.59
1975	0.09	0.41	0.27	0.66	1.07	0.81
1976	0.06	0.52	0.70	0.39	0.32	0.69
1977	0.10	0.35	0.86	0.66	0.35	0.66
1978	0.06	0.43	0.44	1.02	0.22	0.39
1979	0.19	0.55	0.58	0.59	0.89	0.27
1980	0.15	0.29	0.74	0.60	0.54	0.30
1981	0.07	0.63	0.23	0.22	0.43	0.50
1982	0.16	0.54	1.19	0.68	1.12	1.04
1983	0.11	0.36	0.93	1.38	1.08	0.34
1984	0.06	0.20	1.29	1.91	2.43	0.66
1985	0.03	0.34	0.11	0.60	0.64	1.23
1986	0.01	0.13	0.51	0.12	1.42	0.44
1987	0.09	0.02	0.24	0.89	0.07	0.21
1988	0.06	0.23	0.20	0.21	1.61	0.29
1989	0.08	0.32	0.53	0.64	0.69	0.50
Mean	0.08	0.32	0.53	0.64	0.69	0.50

Table 3.6. Virtual population analysis estimates of annual exploitation rates for Pacific cod from the west coast of Vancouver Island (Areas 3C and 3D), age-classes 2-7, 1956-89.

	Age					
Year	2	3	4	5	6	7
1956	0.05	0.25	0.35	0.40	0.22	0.19
1957	0.11	0.36	0.55	0.60	0.41	0.29
1958	0.01	0.32	0.26	0.58	0.26	0.16
1959	0.01	0.17	0.47	0.42	0.57	0.36
1960	0.00	0.11	0.26	0.49	0.33	0.21
1961	0.00	0.04	0.15	0.37	0.35	0.40
1962	0.07	0.05	0.09	0.07	0.16	0.33
1963	0.08	0.12	0.12	0.09	0.02	0.22
1964	0.02	0.09	0.23	0.28	0.35	0.08
1965	0.04	0.25	0.30	0.34	0.29	0.26
1966	0.05	0.32	0.40	0.33	0.54	0.25
1967	0.02	0.23	0.33	0.18	0.36	0.43
1968	0.02	0.18	0.18	0.31	0.25	0.35
1969	0.02	0.16	0.15	0.16	0.38	0.30
1970	0.04	0.07	0.21	0.13	0.06	0.16
1971	0.09	0.19	0.12	0.22	0.13	0.14
1972	0.15	0.24	0.27	0.20	0.25	0.22
1973	0.03	0.19	0.26	0.32	0.26	0.32
1974	0.06	0.08	0.36	0.37	0.44	0.33
1975	0.06	0.25	0.17	0.36	0.50	0.42
1976	0.04	0.30	0.38	0.24	0.20	0.37
1977	0.07	0.21	0.44	0.36	0.21	0.36
1978	0.05	0.26	0.27	0.49	0.14	0.24
1979	0.12	0.31	0.33	0.33	0.45	0.18
1980	0.10	0.18	0.39	0.34	0.31	0.19
1981	0.05	0.35	0.15	0.15	0.26	0.29
1982	0.11	0.31	0.53	0.37	0.52	0.49
1983	0.07	0.22	0.46	0.58	0.50	0.21
1984	0.05	0.13	0.56	0.68	0.74	0.36
1985	0.02	0.21	0.07	0.34	0.35	0.55
1986	0.01	0.09	0.29	0.08	0.59	0.26
1987	0.06	0.02	0.16	0.45	0.05	0.14
1988	0.05	0.15	0.13	0.14	0.63	0.19
1989	0.05	0.20	0.30	0.35	0.37	0.29
Mean	0.05	0.19	0.29	0.33	0.34	0.28

Table 3.7. Canada-U.S. annual nominal catch (landings), standardized equivalent effort, nominal CPUE and CPUE by age (number per hour), for Pacific cod from Queen Charlotte Sound (Areas 5A + 5B), 1956-89.

Year	C-US Land (t)	C-US Eff (h)	C-US CPUE (kg/h)	Age										
				1	2	3	4	5	6	7	8	9	10	11
1956	1753	5312	330	0.1	71.4	52.9	13.8	0.4	4.5	-	0.1	0.5	-	-
1957	2744	3532	777	6.3	197.5	105.6	32.3	5.4	1.3	0.3	0.2	0.3	-	-
1958	1178	5583	211	-	14.1	35.7	18.6	5.5	0.8	0.7	0.1	0.1	-	-
1959	946	4078	232	0.1	32.6	32.3	15.3	5.3	2.1	0.4	0.2	-	-	-
1960	618	4791	129	-	3.1	15.6	11.6	5.0	2.2	0.6	0.2	0.1	-	-
1961	240	3692	65	-	2.2	5.3	4.7	4.1	2.0	0.2	0.3	-	-	-
1962	422	4538	93	-	14.6	6.2	6.1	3.7	4.3	2.4	0.8	0.1	0.1	-
1963	677	4153	163	0.3	29.1	19.5	12.7	1.6	0.7	0.2	0.1	-	0.1	-
1964	1275	4167	306	-	69.3	26.1	9.4	4.7	1.6	0.3	-	-	-	-
1965	1940	4199	462	-	23.7	62.4	53.0	4.2	5.0	1.1	1.2	-	0.1	-
1966	1811	6732	269	0.2	44.9	28.1	13.1	7.0	2.0	0.8	0.2	0.1	-	-
1967	1501	7080	212	-	16.6	22.2	14.1	6.2	3.8	2.3	0.8	0.5	-	-
1968	960	6575	146	0.2	20.7	12.9	12.0	6.2	1.3	0.3	0.2	-	-	-
1969	699	8738	80	0.2	7.5	8.2	7.2	2.0	1.6	0.6	0.4	0.1	-	-
1970	299	3987	75	0.1	15.5	10.8	3.1	1.1	0.3	0.2	0.1	-	-	-
1971	928	6874	135	0.7	29.4	5.9	3.6	3.7	2.3	1.5	0.3	0.2	-	0.2
1972	2320	9547	243	0.2	87.2	21.9	7.4	0.6	0.1	-	-	-	-	-
1973	1914	7250	264	0.3	15.4	29.6	45.2	1.3	0.7	2.5	-	-	0.7	-
1974	2292	11180	205	-	26.7	21.9	8.8	7.2	2.9	0.6	-	-	-	-
1975	2444	8341	293	0.3	69.0	41.8	13.3	4.9	0.4	1.2	-	0.2	-	-
1976	2271	10612	214	0.7	51.5	45.4	8.4	2.0	0.2	0.5	-	0.4	-	-
1977	1268	8234	154	0.9	64.8	22.5	6.3	2.2	0.8	0.4	0.3	-	-	-
1978	1959	7477	262	0.7	27.3	65.5	13.9	2.2	2.3	0.4	0.1	-	0.1	-
1979	1904	6974	273	1.1	83.3	19.8	11.9	5.5	-	0.4	-	-	-	-
1980	1335	6481	206	1.0	58.8	29.3	8.2	1.3	0.7	0.1	-	-	0.1	-
1981	858	4988	172	1.4	37.5	20.0	8.6	2.0	1.0	0.5	0.2	0.1	0.1	-
1982	603	5154	117	-	19.7	22.6	9.2	1.1	1.0	-	-	-	-	-
1983	183	6100	30	-	3.7	6.1	1.5	0.2	0.1	0.1	-	-	-	-
1984	382	5162	74	0.2	13.5	8.7	3.9	1.0	0.4	0.2	0.1	-	-	-
1985	299	4333	69	0.1	9.7	9.7	4.5	0.9	0.4	0.2	-	-	-	-
1986	241	4382	55	0.1	13.6	8.1	6.8	1.9	0.4	0.2	0.1	-	-	-
1987	3242	9678	335	1.2	194.5	9.9	2.0	1.0	0.3	-	-	-	-	-
1988	1849	6651	278	0.6	45.6	31.4	14.9	4.1	1.8	0.8	0.3	0.1	0.1	-
1989	765	7887	97	0.1	18.4	11.5	4.7	1.5	0.6	0.2	0.1	-	-	-

Table 3.8. Canada-U.S. annual nominal catch (landings), standardized equivalent effort, nominal CPUE and CPUE by age (number per hour), for Pacific cod from Hecate Strait (Areas 5C+5D), 1961-89.

Year	C-US Land (t)	C-US Eff (h)	C-US CPUE (kg/h)	Age 1	2	3	4	5	6	7	8	9	10
1961	1616	4391	368	-	21.5	140.6	60.5	11.2	2.0	1.1	1.1	-	-
1962	1690	2735	618	2.0	101.9	153.6	87.9	40.7	16.1	4.8	1.5	1.2	-
1963	2927	3157	927	14.7	170.8	378.7	190.4	60.0	10.4	12.0	3.8	1.6	0.1
1964	5228	3050	1714	1.9	469.9	290.9	122.9	52.8	9.4	1.6	0.5	0.3	-
1965	9119	5500	1658	0.5	58.3	425.2	178.8	39.1	10.9	0.8	0.9	0.1	-
1966	9519	6675	1426	1.1	66.0	228.8	167.8	46.4	11.9	1.6	0.2	0.1	0.1
1967	5112	4755	1075	-	200.1	142.7	86.7	38.4	14.3	4.6	1.3	0.2	0.1
1968	5165	14074	367	0.3	8.1	109.3	27.8	13.5	6.4	1.6	0.5	0.3	-
1969	2959	12078	245	0.2	36.7	24.4	35.0	13.2	3.4	1.8	0.2	0.1	0.1
1970	1339	8868	151	-	15.1	45.1	14.2	3.1	1.9	0.7	0.3	-	0.2
1971	1474	6856	215	0.8	70.4	24.0	15.7	7.9	1.1	0.7	0.5	-	-
1972	2694	4177	645	0.5	238.7	81.9	45.5	14.3	2.4	2.0	0.4	0.9	-
1973	4003	3552	1127	7.4	206.9	239.0	81.6	19.3	10.9	1.9	0.5	0.6	0.2
1974	4764	4630	1029	0.5	250.1	100.4	80.4	26.3	6.9	1.0	0.6	0.5	-
1975	4982	8649	576	0.1	68.3	107.0	42.1	21.6	2.6	4.2	1.7	0.8	0.1
1976	5016	10582	474	0.2	47.1	106.3	29.1	10.4	4.1	1.9	0.2	0.3	-
1977	3523	10124	348	0.1	93.3	54.3	27.3	5.1	3.2	1.0	-	-	-
1978	2102	5904	356	3.6	13.5	76.8	37.1	10.9	1.6	1.2	0.3	-	-
1979	4695	10274	457	0.7	133.6	34.1	44.6	10.5	3.3	0.6	0.3	-	0.1
1980	4540	12473	364	0.5	57.3	75.1	28.5	7.9	2.6	1.0	0.2	0.1	-
1981	3182	15752	202	0.9	26.0	28.2	28.1	9.9	1.4	0.9	-	-	-
1982	2077	5451	381	0.7	41.1	71.3	32.6	10.1	2.9	0.6	0.2	0.2	-
1983	2717	6967	390	0.3	32.9	63.3	37.4	12.8	3.0	0.9	0.2	-	-
1984	1748	5362	326	-	59.1	38.3	30.9	10.9	4.2	0.4	0.4	-	-
1985	1064	7093	150	0.4	10.7	30.9	10.6	3.7	1.9	0.2	0.1	-	-
1986	2099	3923	535	2.2	20.9	46.1	82.0	15.3	7.4	0.9	0.6	-	-
1987	8870	8056	1101	36.5	406.2	85.2	30.1	19.0	6.4	0.1	1.2	-	-
1988	6198	9521	651	0.2	49.9	178.6	61.3	14.4	2.3	1.1	0.1	-	-
1989	4789	10434	459	-	32.7	47.6	73.6	22.3	2.7	1.1	0.4	0.1	-

Table 3.9. Canada-U.S. landings of Pacific cod (t), standardized equivalent effort(h) and numbers landed by age from Areas 5C + 5D during Jan-Dec 1961-89.

	Age									
Year	1	2	3	4	5	6	7	8	9	10
1961	0	94483	617259	265630	49200	8757	4828	4630	0	107
1962	5532	278794	419984	240459	111250	44053	13005	4144	3415	0
1963	46557	539367	1195415	600959	189528	32688	37829	12081	5109	287
1964	5731	1433345	887346	374908	160985	28703	4962	1397	970	0
1965	2778	320794	2338347	983425	214892	60119	4286	5028	443	0
1966	7180	440813	1527053	1119902	309846	79206	10980	1345	987	490
1967	0	951478	678517	412367	182466	68081	21823	6234	1084	450
1968	4758	113731	1538964	390751	190156	90470	23133	7271	3931	479
1969	2736	443830	294943	423158	159911	40803	21276	2812	670	1168
1970	70	134000	399691	125712	27175	16540	5850	2226	0	1714
1971	5364	482507	164353	107418	53931	7557	4622	3572	0	0
1972	2161	997001	341969	190189	59677	9925	8310	1591	3907	0
1973	26237	734844	848850	289878	68588	38713	6575	1929	1979	607
1974	2522	1158125	464625	372447	121809	31744	4528	2743	2212	0
1975	740	590954	925509	364267	187172	22155	36719	14405	6585	496
1976	1927	498597	1124668	308118	109700	43149	20110	2009	2861	0
1977	573	944249	549544	276049	51157	32697	10054	0	382	0
1978	21017	79741	453378	218904	64081	9636	7065	1877	0	0
1979	7113	1372303	349999	458561	107410	33948	5993	3241	0	727
1980	6263	714708	936961	355155	99061	32159	12612	2394	797	0
1981	13985	410256	443602	442459	156516	21770	14159	0	0	0
1982	3758	223988	391374	177963	54912	15550	3462	1176	944	0
1983	2321	228894	441099	260738	89347	21221	6012	1090	281	159
1984	0	317009	205474	165858	58183	22284	2188	1900	193	154
1985	2603	75806	219103	75396	26040	13276	1576	555	0	0
1986	8435	81925	180950	321759	59959	28904	3636	2245	20	146
1987	293764	3272104	686648	242427	152709	51953	1140	9502	306	207
1988	2286	475155	1700220	583233	137007	22374	10554	1355	401	0
1989	386	341503	496329	767970	232531	28076	11275	4277	921	0

Table 3.10. Virtual population analysis estimates of numbers-at-age (thousands) of Pacific cod from Hecate Strait (Areas 5C and 5D), for age-classes 2-7, 1961-89.

	Age					
Year	2	3	4	5	6	7
1961	6663	2589	961	1032	196	25
1962	9788	3580	985	339	531	102
1963	11362	5183	1656	368	107	260
1964	15845	5845	1977	480	70	35
1965	8123	7649	2575	812	149	18
1966	5667	4238	2546	718	293	39
1967	7875	2784	1249	606	175	104
1968	2793	3627	1041	392	204	48
1969	3474	1447	908	295	82	49
1970	4602	1581	582	202	51	17
1971	4987	2419	584	229	91	16
1972	7564	2398	1210	242	87	44
1973	5526	3423	1070	525	90	41
1974	5848	2494	1266	380	238	22
1975	6208	2375	1030	428	122	107
1976	4778	2963	648	310	103	51
1977	5668	2254	830	139	93	26
1978	4270	2422	839	259	41	28
1979	6777	2289	999	303	96	15
1980	3869	2728	1007	227	91	28
1981	3624	1603	833	303	55	27
1982	2713	1698	560	152	58	15
1983	2920	1327	654	181	44	21
1984	4415	1434	413	175	37	9
1985	3504	2192	640	110	55	5
1986	8251	1869	1042	296	42	21
1987	15995	4466	898	342	119	4
1988	4429	6400	1947	320	81	29
1989	3509	2079	2298	654	79	29

Table 3.11. Virtual population analysis estimates of fishing mortality rate (F) for Pacific cod from Hecate Strait (Areas 5C and 5D), age-classes 2-7, 1956-89.

	Age					
Year	2	3	4	5	6	7
1961	0.02	0.37	0.44	0.06	0.06	0.30
1962	0.04	0.17	0.38	0.56	0.12	0.18
1963	0.06	0.36	0.64	1.06	0.51	0.21
1964	0.13	0.22	0.29	0.57	0.75	0.21
1965	0.05	0.50	0.68	0.42	0.73	0.37
1966	0.11	0.62	0.84	0.81	0.43	0.45
1967	0.18	0.38	0.56	0.49	0.70	0.32
1968	0.06	0.78	0.66	0.96	0.83	0.95
1969	0.19	0.31	0.90	1.15	0.99	0.81
1970	0.04	0.40	0.33	0.20	0.55	0.60
1971	0.13	0.09	0.28	0.37	0.12	0.46
1972	0.19	0.21	0.23	0.39	0.16	0.28
1973	0.20	0.39	0.44	0.19	0.80	0.24
1974	0.30	0.28	0.48	0.54	0.20	0.31
1975	0.14	0.70	0.60	0.82	0.28	0.58
1976	0.15	0.67	0.94	0.60	0.77	0.71
1977	0.25	0.39	0.57	0.63	0.60	0.68
1978	0.02	0.29	0.42	0.39	0.37	0.40
1979	0.31	0.22	0.88	0.60	0.62	0.69
1980	0.28	0.59	0.60	0.82	0.60	0.84
1981	0.16	0.45	1.10	1.05	0.72	1.06
1982	0.12	0.35	0.53	0.63	0.43	0.37
1983	0.11	0.57	0.72	0.97	0.95	0.47
1984	0.10	0.21	0.73	0.56	1.34	0.36
1985	0.03	0.14	0.17	0.37	0.38	0.48
1986	0.01	0.13	0.51	0.31	1.87	0.26
1987	0.32	0.23	0.43	0.84	0.82	0.54
1988	0.16	0.42	0.49	0.80	0.44	0.64
1989	0.14	0.37	0.57	0.61	0.61	0.70
Mean	0.14	0.37	0.57	0.61	0.61	0.70

Table 3.12. Virtual population analysis estimates of annual exploitation rates for Pacific cod from Hecate Strait (Areas 5C and 5D), age-classes 2-7, 1956-89.

	Age					
Year	2	3	4	5	6	7
1961	0.01	0.24	0.28	0.05	0.04	0.20
1962	0.03	0.12	0.24	0.33	0.08	0.13
1963	0.05	0.23	0.36	0.52	0.31	0.15
1964	0.09	0.15	0.19	0.34	0.41	0.14
1965	0.04	0.31	0.38	0.26	0.40	0.24
1966	0.08	0.36	0.44	0.43	0.27	0.28
1967	0.12	0.24	0.33	0.30	0.39	0.21
1968	0.04	0.42	0.38	0.49	0.44	0.48
1969	0.13	0.20	0.47	0.54	0.50	0.44
1970	0.03	0.25	0.22	0.13	0.32	0.35
1971	0.10	0.07	0.18	0.24	0.08	0.28
1972	0.13	0.14	0.16	0.25	0.11	0.19
1973	0.13	0.25	0.27	0.13	0.43	0.16
1974	0.20	0.19	0.29	0.32	0.13	0.20
1975	0.10	0.39	0.35	0.44	0.18	0.34
1976	0.10	0.38	0.48	0.35	0.42	0.40
1977	0.17	0.24	0.33	0.37	0.35	0.38
1978	0.02	0.19	0.26	0.25	0.24	0.25
1979	0.20	0.15	0.46	0.35	0.35	0.39
1980	0.18	0.34	0.35	0.44	0.35	0.45
1981	0.11	0.28	0.53	0.52	0.40	0.52
1982	0.08	0.23	0.32	0.36	0.27	0.24
1983	0.08	0.33	0.40	0.49	0.48	0.29
1984	0.07	0.14	0.40	0.33	0.59	0.23
1985	0.02	0.10	0.12	0.24	0.24	0.29
1986	0.01	0.10	0.31	0.20	0.69	0.18
1987	0.20	0.15	0.27	0.45	0.44	0.32
1988	0.11	0.27	0.30	0.43	0.28	0.37
1989	0.10	0.24	0.33	0.36	0.35	0.39
Mean	0.09	0.23	0.32	0.34	0.33	0.29

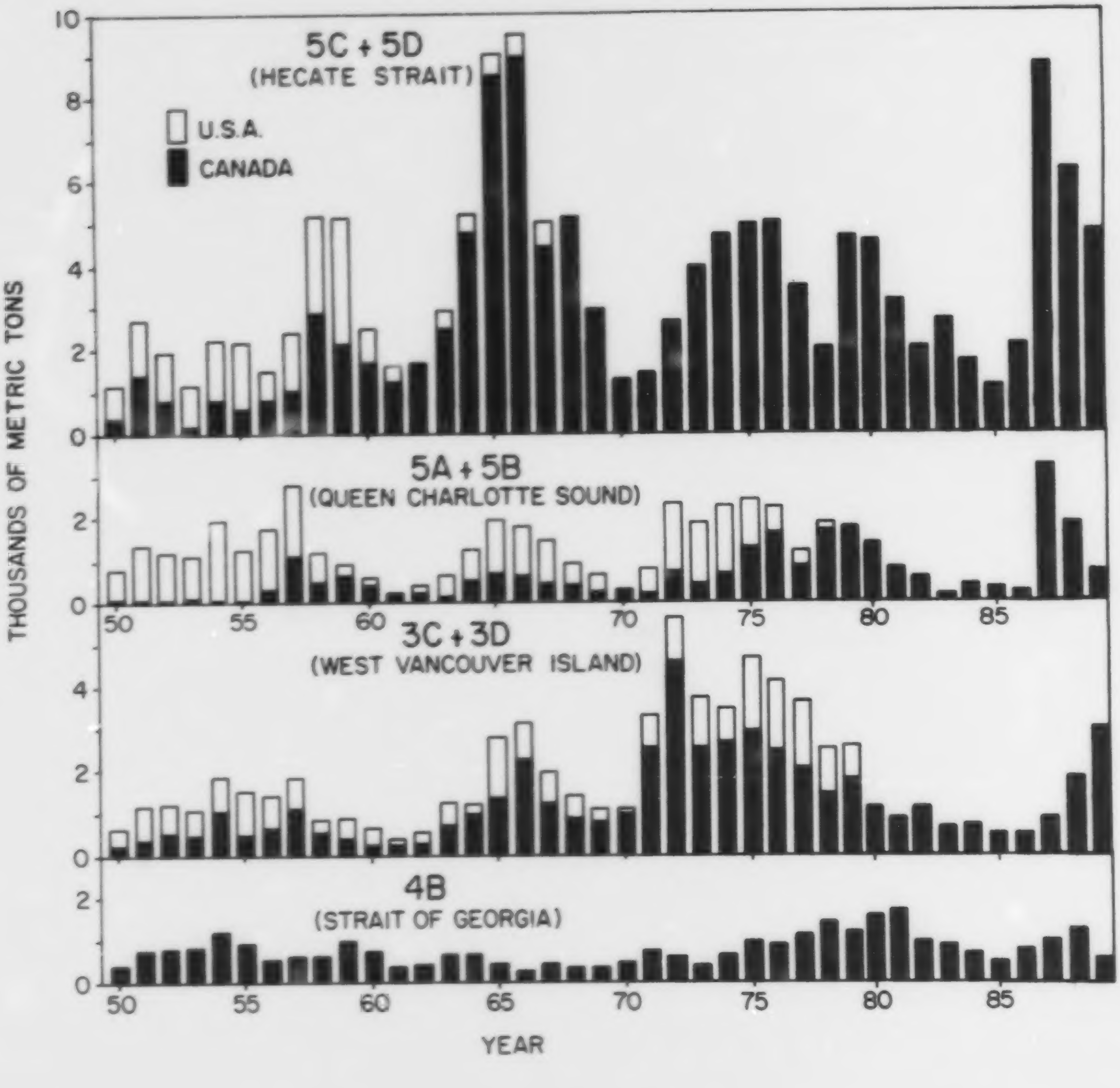


Fig. 3.1. Canada-U.S. annual nominal catch (landings) of Pacific cod, by region, 1950-89.

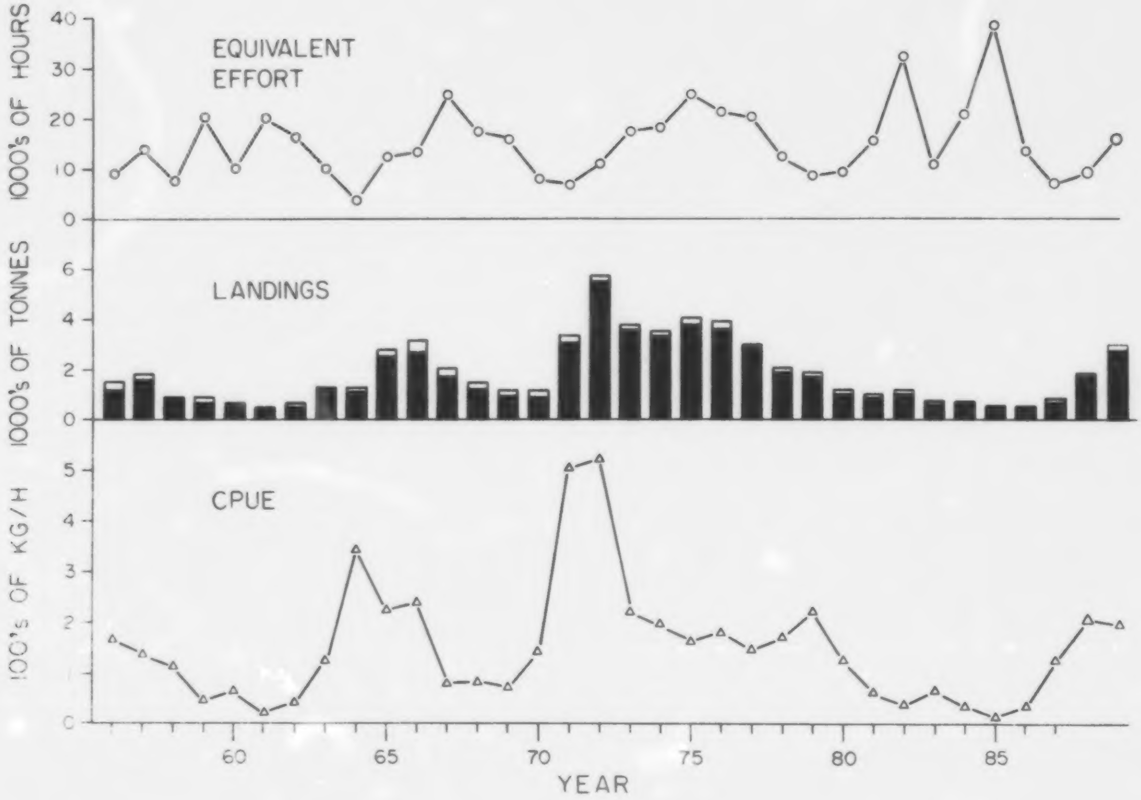


Fig. 3.2. Standardized Canada-U.S. landing statistics for Pacific cod from the west coast of Vancouver Island, 1956-89. Shaded portion of columns from Area 3C; clear portion from Area 3D.

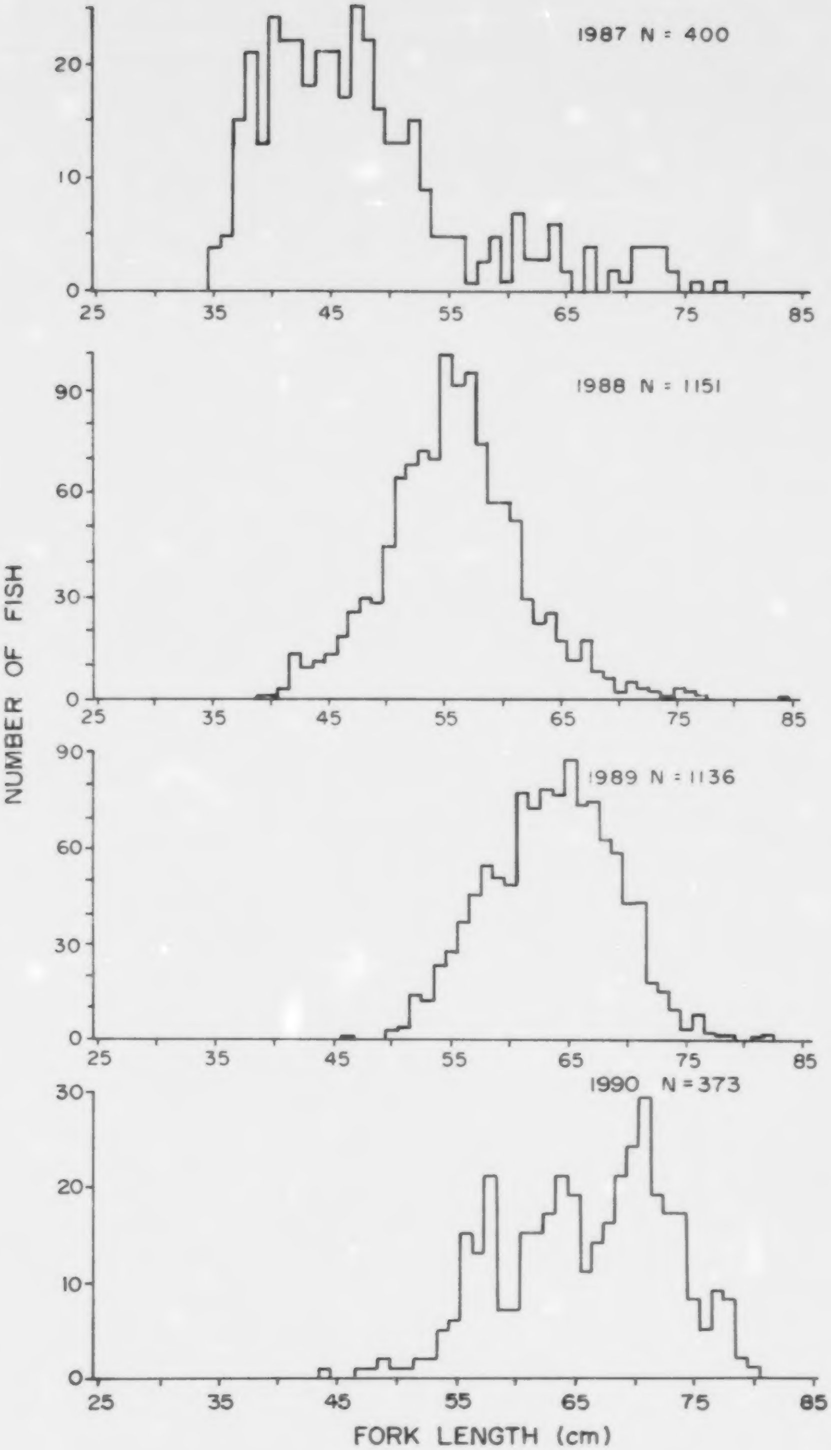


Fig. 3.3. Length frequency of Area 3C Pacific cod for the second quarter (April-June, inclusive) of 1987, 1988, 1989 and 1990. Number of fish measured by year (N) given in the panels.

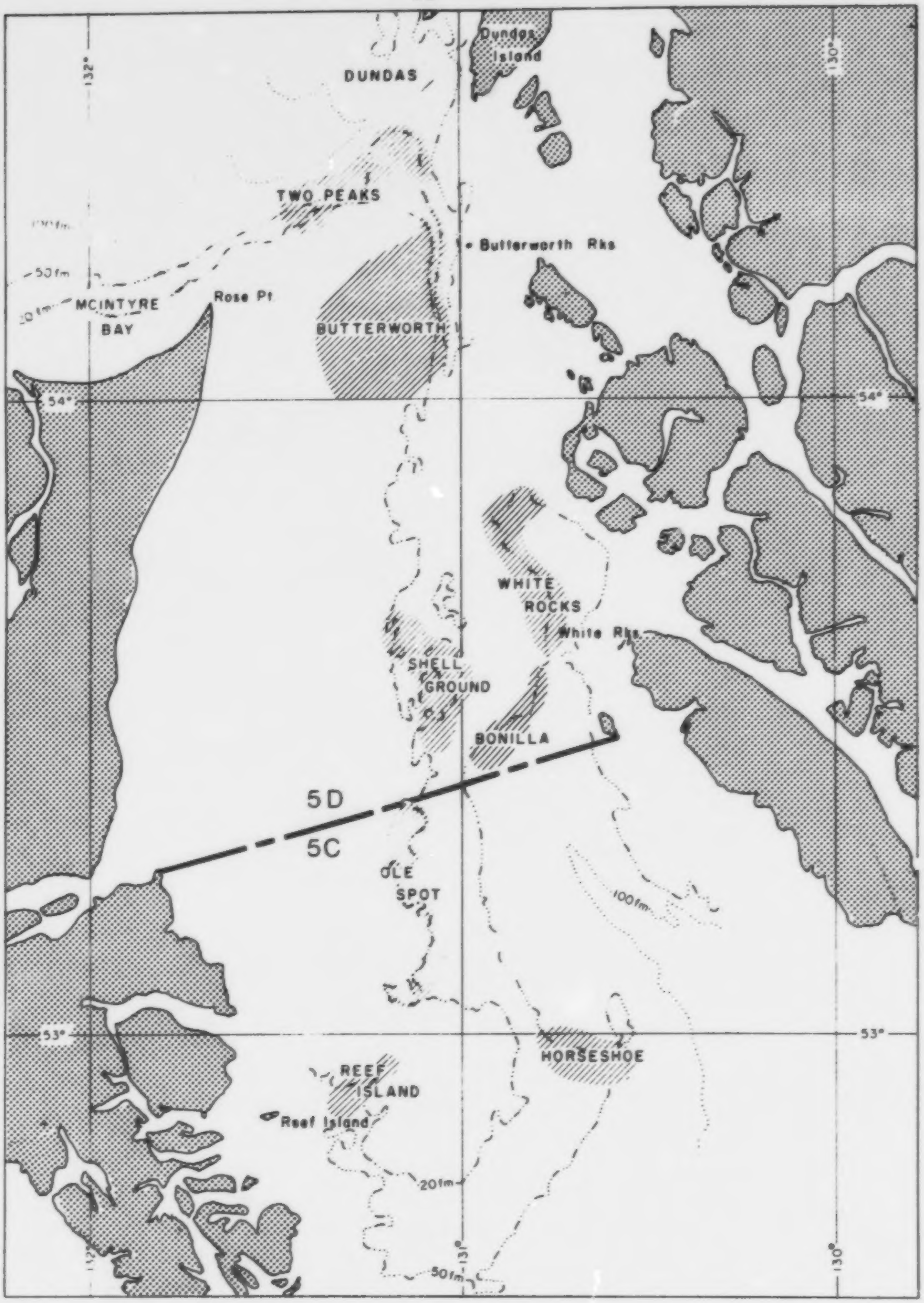

Dundas Island
DUNDAS
132°
130°
TWO PEAKS
Butterworth Rks
50 fm
20 fm
MCINTYRE BAY
Rose Pt
BUTTERWORTH
54°
WHITE ROCKS
White Rks
SHELL GROUND
BONILLA
5D
5C
OLE SPOT
100 fm
53°
HORSESHOE
REEF ISLAND
Reef Island
20 fm
131°
50 fm

Fig. 3.4. Important trawling grounds for Pacific cod in Hecate Strait.

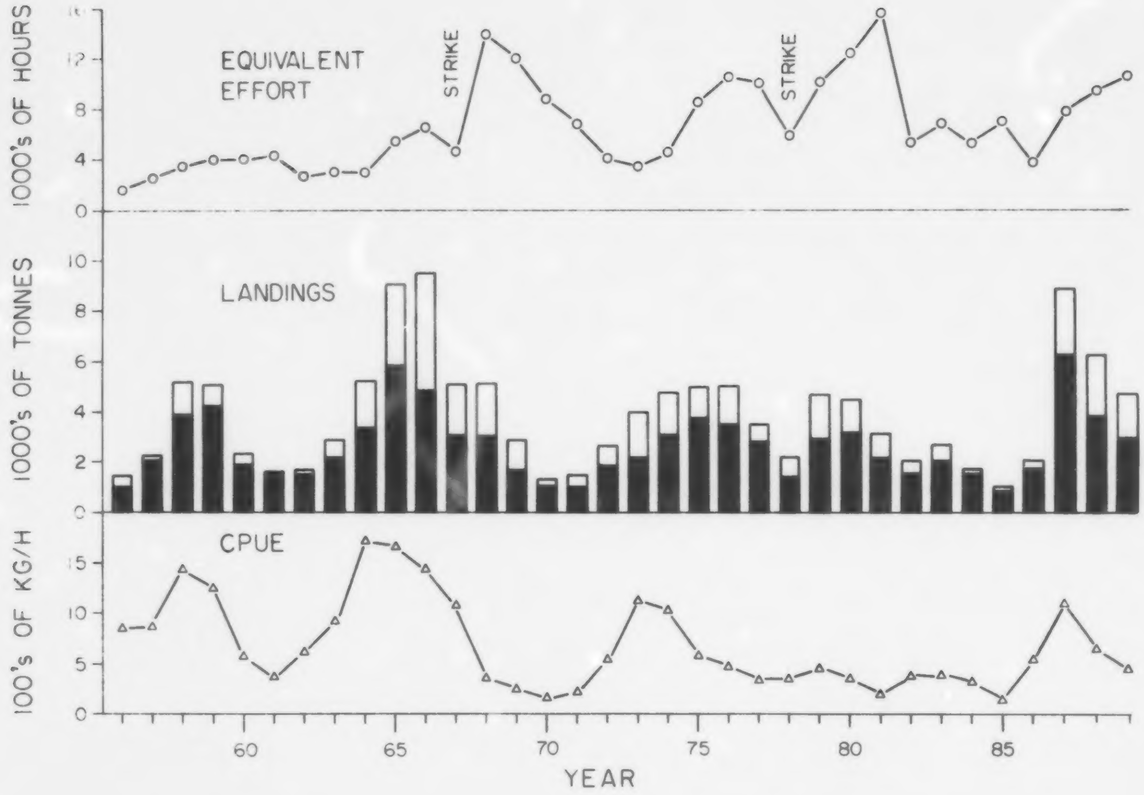


Fig. 3.5. Standardized Canada-U.S. landing statistics for Pacific cod from Hecate Strait, 1956-89. Shaded portion of columns from Area 5D; clear portion from Area 5C. "Strike" indicates years when a component of the industry was on strike. This reduced the total effort for the year but did not influence CPUE.

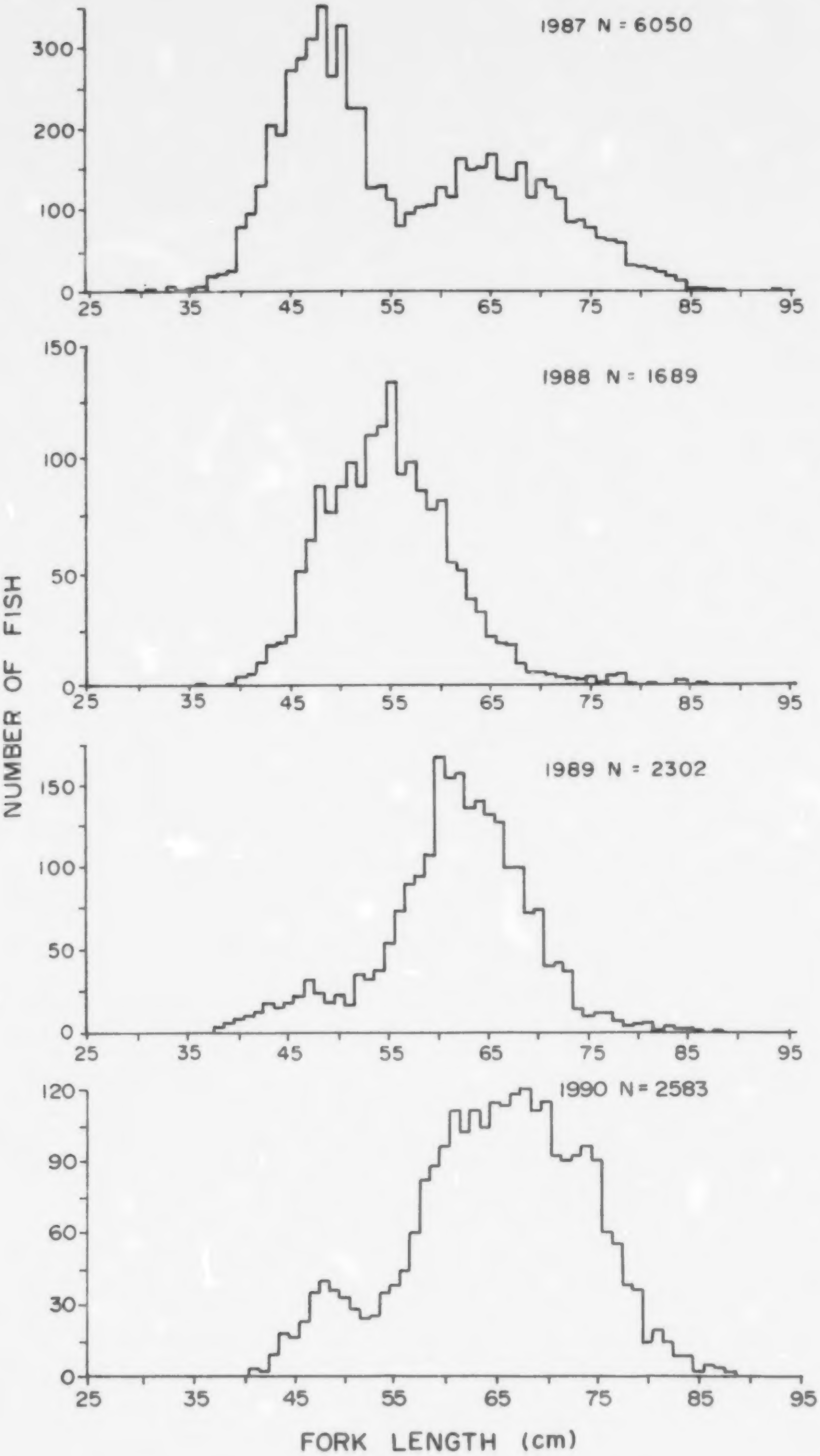


Fig 3.6. Length frequency of Areas 5C and 5D Pacific cod for the first quarter (January-March inclusive) of 1987, 1988, 1989 and 1990. Number of fish measured by year (N) given in panels.

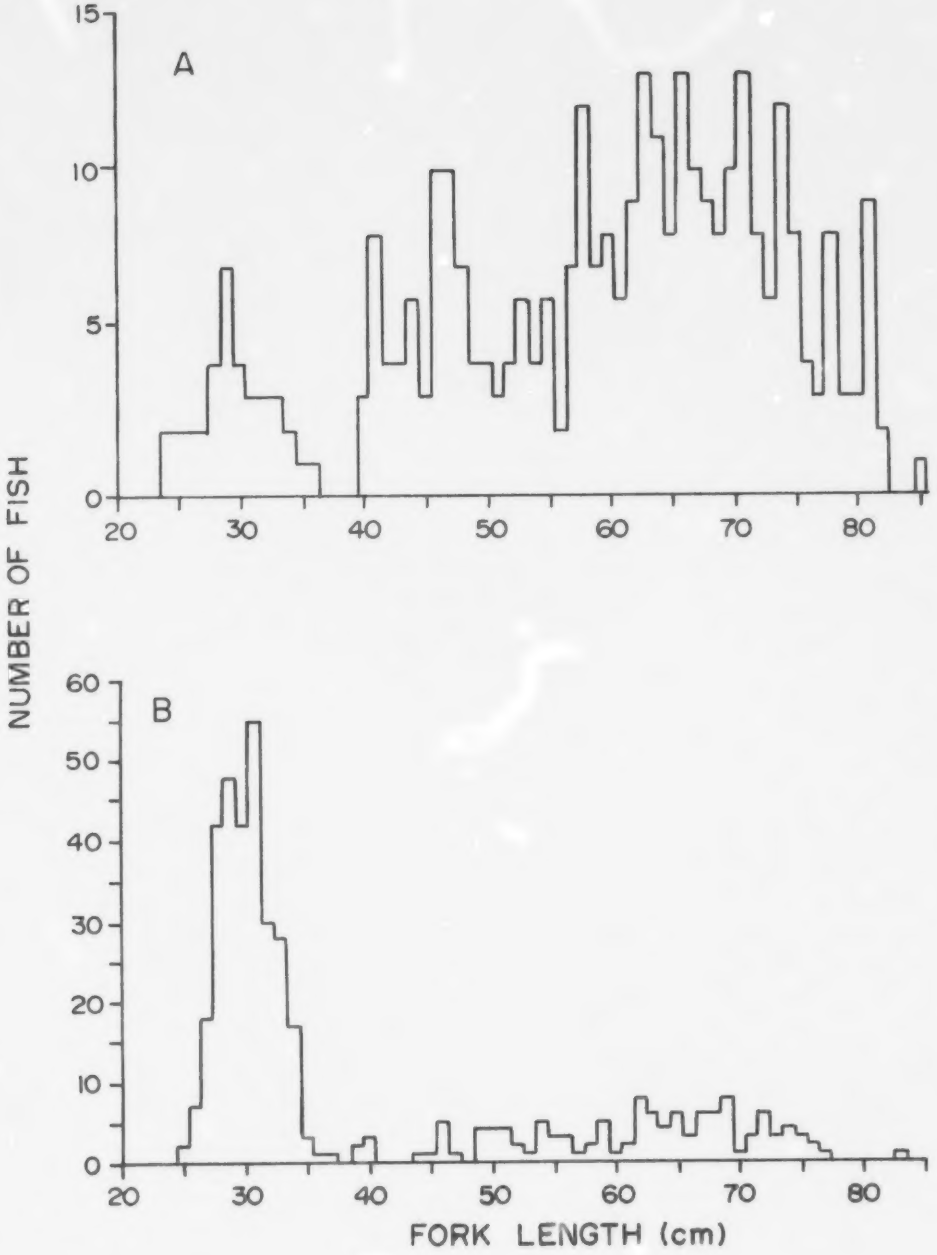


Fig. 3.7. Length frequencies of unsorted commercial samples of Pacific cod from Hecate Strait. a) February 23, 1990, White Rocks Ground, N=335; b) February 25, 1990, Horseshoe Ground, N=415.

4.0. FLATFISH

by J. Fargo

4.0.1. General Introduction

These stock assessments employ a variety of techniques, but they are they dependent on two basic types of data, 1) standardized landing statistics and 2) biological data in the form of size and/or age composition. The standardization procedure used for landing statistics is described, briefly, below.

Landing statistics, have been standardized, where possible, to account for changes in CPUE due to increases in vessel horsepower. The standardization procedure involves the use of a multiplicative log-linear model which incorporates vessel horsepower effects on CPUE (Fargo 1989). The model does not fully account for increased fishing power over time. It only accounts for changes in fishing power due to changes in fleet composition relative to horsepower. It is similar to models used by Gavaris (1980) and Kimura (1981). The data are partitioned according to categories of year and horsepower class, and an index of relative CPUE (standardized) is produced for each year. The CPUE index for the last year in the time series is set equal to 1. CPUE for other years is scaled relative to this value. The relative CPUE index for each year is multiplied by the observed CPUE (kg/h) for the current year to produce a CPUE time series for each species/stock.

Estimates of sustainable yield for most flatfish stocks are produced from analysis of standardized landing statistics and yield per recruit analysis (data permitting) on an individual stock basis. Where possible, several independent abundance indices are used for monitoring the condition of stocks and estimating sustainable yields. Yield options for 1990-91 are summarized in Table 4.1.

For stocks where data are not sufficient to permit yield per recruit analysis, a length frequency simulator (Rasmussen and Stanley 1988) has been employed to determine the rate of fishing mortality, for the stock. The model utilizes estimates of growth rate (k) and natural mortality (M) to derive theoretical length frequencies for different levels of fishing mortality. The model assumes that changes in size composition are due only to effects of natural and fishing mortality. We used the model results qualitatively. We first decided which simulated (model) length frequency best matched the right-hand limb (fully recruited age groups) of the sample length frequency. We then assumed the F value that generated this simulated length frequency had been sustained by the stock in question. The model is inadequate when significant changes in size composition are caused by factors other than natural and fishing mortality, as, for example, by changes in recruitment. Total mortality would be overestimated with increases in recruitment and underestimated with decreases in recruitment.

We also used length frequency anomalies to estimate the level of recruitment for petrale sole and Hecate Strait English sole and rock sole. These anomalies represent the deviations from the long-term means (1946-89) in the numbers of fish caught per length (centimeter) interval. Samples are standardized to 1000 fish prior to computing anomalies, to eliminate any bias that might arise because of unequal sample sizes. The vertical axis in the anomalies represents deviations from the longterm mean of numbers of fish caught per centimetre interval, while the horizontal axis represents 1 centimetre intervals for different size ranges, depending on the species assessed. Clear areas in the anomalies represent above average numbers of fish observed for those length intervals for that year's biological samples. The shaded areas in the anomalies represent below average numbers of fish observed for those length intervals for that year's biological samples. A succession of clear areas moving from left to right over a series of consecutive years indicates the contribution of a year-class to the fishery.

4.1. Coastwide

Yield options are not proposed for flatfish species on a coastwide basis.

4.2. Strait of Georgia

Yield options are not proposed for flatfish for this region.

4.3. West Coast of Vancouver Island

4.3.1. Petrale Sole

4.3.1.1. Introduction

The petrale sole (Eopsetta jordani) population off the west coast of Vancouver Island is thought to be composed of two stocks on the basis of tagging experiments conducted in the 1960s (Ketchen and Forrester 1966) (Pedersen 1975b). The "northern" stock occupies Areas 3D-5D while the "southern" stock occupies both the Canadian and U.S. portions of Area 3C.

4.3.1.2. Fishery

Analyses of Ketchen and Forrester (1966) and Pederson (1975a) have suggested that fishery effects on this species appeared to be overshadowed by environmentally induced variations in recruitment. The majority of the annual catch (70%) is accounted for by a fishery in the first quarter of the year that targets on spawning aggregations of the two stocks in deepwater (200-400 fathoms).

4.3.1.3. Landing Statistics

Landings for the "southern" stock increased to 588 t in 1989 from 365 t in 1988 while landings for the "northern" stock were 549 t in 1989 as compared to 576 t in 1988 (Tables 4.2-4.3 and Figures 4.1-4.2).

4.3.1.4. General Biological Information

Biological samples collected at ports-of-landing for 1986-1989 were added to the data series for the "southern" stock (no length-frequency time series for the "northern" stock exists) and a time series of length frequency anomalies were produced (Section 4.0.1) from 1966-89. The previous time series (1966-86) was presented in Fargo (1988). The anomaly for 1988 indicated no strong recruitment occurring for this stock (Fig. 4.3). The anomaly for 1989 indicates that current recruitment is above average. This may be the start of an increase in recruitment for the stock. This will have to be confirmed with additional years' data.

4.3.1.5. Estimation of Fishing Mortality

Fishing mortality for the 'southern' stock was estimated using the following procedure. Size composition data for female petrale sole for 1989 were compared to theoretical length frequencies from a simulation model (Section 4.0.1.) developed by Rasmussen and Stanley (1988). Estimates of growth and natural mortality for female petrale sole, used for the simulations, were taken from Ketchen and Forrester (1966), and are:

von Bertalanffy growth
parameters: L_{∞}- 58.6 cm
k - 0.167
t_o - -0.27
Instantaneous rate of
natural mortality: M - 0.20

Inspection of the right hand limb of theoretical and 1989 sample length frequencies indicates that the 'southern' stock has sustained a fishing mortality (F) of about 0.2 (Fig. 4.4).

4.3.1.6. Condition of the Stocks

Petrale sole stocks off the west coast of Vancouver Island are considered to be at low levels of abundance because recruitment for these stocks has been low for at least the last decade. Removals from the "southern" stock in the 1980s do not appear to have resulted in excessive fishing mortality. Recruitment may be increasing for the 'southern' stock as well, but this will require corroboration with additional biological information. As a caveat, if recruitment is increasing, length frequency simulation results would overestimate F for this stock (Sec. 4.0.1.).

4.3.1.7. Yield Options

(1) Low risk-sustainable option: A 44,000 lb. trip limit regulation for petrale sole is in effect, coastwide, from January 1-March 31. The January-March period corresponds to the spawning time for petrale sole, a period when these stocks are particularly vulnerable to exploitation. This regulation is aimed at reducing a target fishery on petrale sole while stocks are low and helps to offset significant declines in stock abundance. The trip limit for petrale sole could be considered applicable only to the west coast of Vancouver Island rather than as a coastwide regulation.

(2) High risk-sustainable option: Unrestricted fishery. Previous analyses have suggested that petrale sole

stock size has no effect on recruitment for the specie, and that at least the "southern" stock has not been overfished. As a caveat to this option, all previous age-structured analyses were conducted when petrale sole stocks were at higher levels of abundance than they are now. It is still possible that recruitment overfishing has occurred. This hypothesis will require corroboration through updating the age composition database.

4.3.2. Dover Sole

4.3.2.1. Introduction

Dover sole (Microstomus pacificus) are found in commercial abundance along the Pacific coast from California to Alaska (Alverson 1960). They inhabit relatively shallow (50-80 fathoms, 91-146 metres) depths over mud bottom during late spring-fall and migrate to deepwater (200-500 fathoms, 366-915 metres) offshore areas to spawn during winter-spring. Abundance of this species has been shown to decrease with increasing latitude (Fargo et al. 1985). The largest stocks are found off California. Stocks off Oregon, Washington, and British Columbia are progressively less abundant.

4.3.2.2. Fishery

The deepwater trawl fishery for Dover sole off the west coast of Vancouver Island began in the 1960s and involved, exclusively, U.S. trawlers. This fishery dissolved in 1978 with the advent of extended Canadian jurisdiction. In the early 1980s, with increasing quota management of groundfish stocks off the west coast of Canada, Canadian fishermen became interested in harvesting new, 'non-quota' stocks, and the deepwater fishery off the west coast of Vancouver Island resumed. The fishery takes place between January-April on a spawning population. Landings from this fishery were significant enough to warrant assessment for the first time in 1989.

4.3.2.3. Landing Statistics

Canadian landing statistics were compiled for Areas 3C and 3D for the period 1980-88 (Table 4.4.). U.S. landings from the Canadian portion of Area 3C and Area 3D prior to 1978 never exceeded 500 t. No effort-CPUE figures are available for the U.S. fishery. Landings in 1989 were 1328 t, up from 514 t in 1988. CPUE was 569 kg/h in 1989, similar to the 1988 CPUE of 568 kg/h. Effort in 1989 was 2334 hours, up from 905 hours in 1988. CPUE shows little trend from 1980 to 1989. However, the extremely low landings (few observations) from 1983-87 may make CPUE for these years an unreliable indicator of stock abundance. If these years are removed from the CPUE time series, no trend is observed. Removals of more than 1000 t have occured only in 1989 and 1990. The effect of catch in a given year, on stock abundance, is often evaluated by examining the effect on CPUE in subsequent years (Gulland 1983). The effect of removals of 1300 t on the stock in 1989 can only be evaluated, at present, by examining the 1990 CPUE figure. A preliminary estimate of the 1990 CPUE is 717 kg/h. This suggests that removals of 1300 t in 1989 do not appear, initially, to have had a negative effect on the stock abundance. CPUE has proved to be a reliable index for montoring changes in abundance and estimating MSY for Dover sole stocks in Area 5C-E, and off the Oregon and Washington coasts.

4.3.2.4. General Biological Information

Size composition data for 1989 for Area 3C-D Dover sole were examined and compared with size composition data from the 1981 biomass survey for Dover sole off the west coast of Vancouver Island (Carter et al. 1981) (Figs. 4.5-4.6). The mean length for Dover sole males in Area 3CD in 1989 was 36.9 cm, compared to 38.7 cm for males in the 1981 sample. The mean length for Dover sole females for the 1989 sample was 41.1 cm compared to 41.9 cm for the 1981 samples. There is little change in mean length or size composition for Dover sole in Areas 3C-D between 1981 and 1989. However, there are differences in mean length between Dover sole in Areas 3CD and Areas 5CDE. The mean lengths for males and females in Area 5CDE for 1989 were 41.6 and 47.9 cm, respectively. An examination of size composition data for Washington and Oregon Dover sole during the early years of that fishery (Westrheim and Morgan 1963), revealed that the mean lengths of males and females of these stocks were similar to those of Dover sole in Areas 3CD.

4.3.2.5. Estimation of Fishing Mortality

Fishing mortality for Area 3C-D Dover sole was estimated using the following procedure. Size composition data for female Dover sole for 1989 was compared to theoretical length frequencies produced from a simulation model (Section 4.0.1) developed by Rasmussen and Stanley (1988). Growth parameters estimated for female Dover sole off Washington-Oregon (Bob Demory, pers. commun.) were used as input for the model. The input parameters used were:

von Bertalanffy
growth parameters: L_∞ - 49.9 cm
k - 0.100
t_0 - -1.74
Instantaneous rate
of natural mortality: M - 0.15

Simulated length frequencies were compared with the 1989 Dover sole female size composition data for Area 3CD (Figure 4.7). Observation of the right hand (descending) limb of theoretical and sample length frequencies indicates that Area 3CD Dover sole have sustained a fishing mortality greater than 1.0. Two possibilities, alone or in combination, can account for the high fishing mortality estimated from length simulations. The first is that the growth/natural mortality parameters for this stock are different from those for the Oregon stock which were used in the length simulations. The second is that the Area 3CD stock is a transboundary stock that has been previously fished by U.S. fishermen.

4.3.2.6. Condition of the Stock

In last years' assessment (Fargo 1990), the size of this stock was assumed to be intermediate to stocks off the coast of Washington State and Area 5C-E. The estimated MSYs for these two stocks are 2400 t and 1000 t, respectively. CPUE data indicate that yields of 1300 t may be sustainable for the Area 3CD stock, though only one year's observation can be used to evaluate removals at this level. Size composition data indicates that there has not been an observable change in mean lengths for males or females between 1981 and 1989. Length frequency simulations, however, suggest that this stock has had a significant exploitation history. The results of the length simulations can not be weighted heavily for this assessment until age composition data for the stock has been compiled, growth parameters estimated and length simulations re-run.

4.3.2.7. Yield Options

Low risk sustainable yield option -- A yield of 500 t, equivalent to the catch in 1988 at the outset of this fishery, and the maximum catch observed from the U.S. fishery in the 1960s and 1970s, would minimize the risk of overfishing for the Dover sole stock in Area 3CD.

Sustainable yield option -- Based on shorterm trends in CPUE, yields of 1300 t appear sustainable. As a caveat to this option, additional year's CPUE data are necessary to accurately evaluate the effect of 1300 t annual removals on stock abundance.

High risk sustainable yield option -- Yields of 2000 t, may be sustainable if this is a discrete stock that is intermediate in size to stocks off the Washington coast and in northern British Columbia. U.S. landings of Dover sole off Washington state have averaged 2100 t over the last 10 years (Pacific Marine Fisheries Commission Groundfish Data Series). This option carries with it a greater risk of overfishing for the stock.

4.4. Queen Charlotte Sound

4.4.1. Rock Sole

4.4.1.1. Introduction to Area 5A

The rock sole (Lepidopsetta bilineata) is a minor component of the shelf, on-bottom trawl fishery in Area 5A. The Area 5A population is considered to be a separate stock on the basis of results of tagging experiments conducted in the 1950s and 1960s (Ketchen 1982). The other principal members of this multispecies fishery are Pacific cod (Gadus macrocephalus) and lingcod (Ophiodon elongatus). Rock sole are caught primarily in the 40-50 fathom depths of Cook Bank while Pacific cod and lingcod are caught in the 40-70 fathom depths. Standardized landing statistics are the basis for this assessment.

4.4.1.2. The Fishery

Landings from the multispecies fishery in Area 5A have been dominated by lingcod and Pacific cod. Most catches of rock sole are taken incidentally to these species. Fishery production for Area 5A rock sole is dependent upon recruitment, and recruitment has been highly variable over time. A trip limit regulation is the basis for management of rock sole in British Columbia. A coastwide trip limit of 30,000 lb. was in effect in 1989.

4.4.1.3. Landing Statistics

Standardized landing statistics were derived following the procedure outlined in Section 4.0.1, and are presented in Table 4.5 and Figures 4.8.-4.9. Landings of rock sole in Area 5A increased to 143 t in 1989, from 128 t in 1988, while effort decreased to 777 h in 1989 from 842 h in 1988. CPUE for rock sole in Area 5A increased to 184 kg/h in 1989 from 152 kg/h in 1988. Pacific cod and lingcod continue to be the primary targets of this fishery.

4.4.1.4. Condition of the Stock

CPUE for Area 5A rock sole shows little trend since the start of the time series in 1956. We suggest that the rock sole stock in Area 5A has been at a stable level of abundance over this time period. Removals during this period ranged from 100-550 tonnes. Analysis of size composition data for 1988 (there were no samples taken in 1989) indicated that recruitment for the stock was above average (Fargo 1990).

4.4.1.5. Yield Options

Low risk-sustainable yield option: A yield of 250 t is considered to be sustainable for the current recruitment level.

The 30,000 lb. coastwide trip limit regulation for rock sole is consistent with this option.

High risk-sustainable yield option: Yields greater than 500 t increase the risk of overfishing for this stock.

4.4.1.6. Introduction to Area 5B

Rock sole is a minor component of the multispecies shelf, on-bottom trawl fishery in Area 5B. The Area 5B population is considered to be a separate stock on the basis of results of tagging experiments conducted in the 1950s and 1960s (Ketchen 1982). Pacific cod and lingcod are the major components in this multispecies fishery. Standardized landing statistics and size composition data are the basis for this assessment.

4.4.1.7. The Fishery

Catches of rock sole in Area 5B have traditionally come from the 40-50 fathom depth range on the outer edges of Goose Island Bank, which is considered to have good "trawlable" bottom. There has been speculation among fishermen over the years that rock sole occupy the top of the bank (10-39 fathom depths) which is composed mainly of rough bottom type, not amenable to trawl capture of flatfish. Suitable habitat is available for rock sole on top of the bank, and rock sole in other areas along the Pacific coast are most abundant at shallower (10-39 fathom) depths. Fishery production for Area 5B rock sole has been dependent upon recruitment, which has been highly variable. A trip limit regulation is the basis for management of the rock sole fishery in British Columbia. A coastwide trip limit of 30,000 lb. was in effect in 1989.

4.4.1.8. Landing Statistics

Standardized landing statistics were derived following the procedure outlined in Section 4.0.1, and are presented in Table 4.6 and Figs. 4.10-4.11. Landings decreased to 260 t in 1989 from 272 t in 1987, while effort increased to 1156 h in 1989, from 1106 h in 1988. CPUE for 1989 was 225 kg/h, down from 246 kg/h in 1988. There is no long-term trend in CPUE (1956-88). Currently, CPUE is close to the highest levels recorded for the time series. Short term trends in CPUE coincide with recruitment fluctuations and abundance for the species. Over the last three years, there has been an upward trend in CPUE which has mirrored a recruitment increase.

4.4.1.9. General Biological Information

Size composition catch rate data for 1987 and 1989 (no samples were taken in 1988) indicate that there was a significant increase in recruitment in 1987, but that by 1989, the contribution to the fishery from this is beginning to lessen.

4.4.1.10. Condition of the Stock

On the basis of recent trends in CPUE, the Area 5B stock is considered to be at an above average level of abundance due to above average recruitment. CPUE has mirrored changes in recruitment/abundance estimated using length frequency anomalies. CPUE has been stable over the last three years with removals of approximately 250 t annually. Removals as high as 600 t in the past do not appear to have produced any lasting effect on CPUE (abundance).

4.4.1.11. Yield Options

Low risk-sustainable yield option: A yield of 250 t is considered to be sustainable for the Area 5B stock. The coastwide 30,000 lb. trip limit for rock sole is consistent with this option.

High risk-sustainable option: Yields greater than 600 t have produced short-term declines in CPUE in the past which indicates an increased risk of overfishing.

4.5. Hecate Strait

4.5.1. Rock Sole

4.5.1.1. Introduction to Area 5C

The rock sole is a minor component in a multi-species on-bottom trawl fishery in Hecate Strait, along with English sole (*Parophrys vetulus*) and Pacific cod. The Area 5C rock sole stock has been defined using abundance trends from landing statistics, size composition analysis and results of a 1982 tagging experiment (Fargo and Westrheim 1987). Standardized landing statistics and size composition data are the basis for this assessment.

4.5.1.2. Fishery

The fishery for rock sole in Area 5C is seasonal. The majority (80%) of the landings occur during April-September. The spring fishery targets predominantly on a spawning population at Reef Island-Cumshewa grounds while summer and fall landings come mainly from the multispecies trawl fisheries at Horseshoe and Ole Spot grounds. A trip limit regulation is the basis for management of the rock sole fishery. A coastwide trip limit of 30,000 lb. was in effect in 1989.

4.5.1.3. Landing Statistics

Standardized landing statistics were derived following the procedure outlined in Section 4.0.1, and are presented in Table 4.7 and Figs. 4.12-4.13. Landings increased to 406 t in 1989 from 189 t in 1988. Landings for 1990 are projected to be about 400 t. Effort increased to 1476 hours in 1989 from 545 hours in 1987. CPUE for rock sole in Area 5C decreased to 275 kg/h in 1989, from 347 kg/h in 1988. No longterm trend in CPUE is apparent. Short-term fluctuations in CPUE coincide with fluctuations in recruitment for the stock. CPUE has decreased over the last 3 years, suggesting that the current recruitment for the Area 5C stock is not as significant as it is for rock sole stocks in other areas.

4.5.1.4 General Biological Information

The length frequency anomaly time series for Area 5C rock sole (Fargo 1988) has been updated with 1988-89 samples (Fig. 4.14). The anomalies for 1988 and 1989 indicate a decreased contribution to the fishery from the above average recruitment in 1987. This trend is expected to continue if recruitment follows the historical pattern for the stock.

4.5.1.5. Condition of the Stock

The Area 5C rock sole stock is considered to be at an average level of abundance, with fishery contribution of the strong recruitment in 1987 decreasing. This is based on trends in standardized CPUE and analysis of size composition data.

4.5.1.6. Yield Options

Low risk-sustainable yield option -- A yield of 100 t, equivalent to yield for years (1981-86) prior to the strong recruitment beginning in 1987 is considered to be a low risk sustainable yield.

High risk-sustainable yield option -- A yield greater than 400 t constitutes a higher risk of overfishing for this stock, at the present time. Landings in 1989 were approximately 400 t. Thus, the 30,000 lb. coastwide trip limit allowed a removal of 400t in 1989.

4.5.1.7. Introduction to Area 5D

The rock sole population in Area 5D is one of the most intensively studied marine fish populations in British Columbia (Forrester and Thomson 1969; Fargo and McKinnell 1989). For the past 40 years the stock has been characterized by cyclic abundance trends attributed to fluctuations in recruitment (Fargo 1989). Large year-classes have been produced by this stock about once a decade, since monitoring began in the late 1940s. Ocean temperature at the time of spawning (optimum = 6.3°C) and stock size have been suggested as important factors in determining year-class production (Fargo and McKinnell 1989). Standardized landing statistics and yield per recruit analysis are the basis for this assessment.

4.5.1.8. The Fishery

The fishery for rock sole in Area 5D is mainly a seasonal one. The majority (80%) of the landings occur during April-September. Principal fishing grounds are Two Peaks and Butterworth. Area 5D rock sole occupy depths of 10-40 fathoms, but are most concentrated at 10-29 fathoms. They are also caught incidentally to Pacific cod and English sole at 30-49 fathoms. Fishery production for the Area 5D stock is dependent upon recruitment and recruitment has been highly variable over time. A trip limit regulation is the basis for management of the rock sole fishery in British Columbia. A coastwide trip limit of 30,000 lb. was in effect in 1989.

4.5.1.9. Landing Statistics

Standardized landing statistics were derived following the procedure outlined in Section 4.0.1. and Fargo (1989), and are presented in Table 4.8 and Figs. 4.15-4.16. Landings in 1989 were 1016 t, down from 1213 t in 1988. Landings for 1990 are projected to be around 800 t. The level of effort in 1989 was 3398 h, down from 5274 h in 1987. CPUE increased to 299 kg/h in 1989 from 230 kg/h in 1988. A long-term declining trend in CPUE (1956-1989) is apparent for the stock.

4.5.1.10. General Biological Information

The length frequency anomaly time series (Fargo 1988) has been updated with 1988-89 samples (Figure 4.17). It appears that the above average year-classes (1984,85) which began contributing to the fishery in 1988 are still making a strong contribution to the fishery in 1989. If they are consistent with strong recruitment in the past, this contribution to the fishery will continue for another 2-3 years and landings will continue to be above average over this time period.

Catch-at-age data used for the virtual population analysis and yield simulations for Area 5D rock sole in the 1989 assessment (Fargo 1989) are presented in Table 4.9. These data were inadvertently omitted from the 1988 assessment.

4.5.1.11. Condition of Stock

Sustainable yield in 1989 was estimated by yield-per-recruit analysis to be 800-1000 t (Fargo 1990), based on the upper and lower bounds for above average recruitment observed in the past. It now appears that the strong year-classes observed in 1987, 1988 is continuing in 1989. Contribution to the fishery from these year-classes should continue for the next 2-3 years. Using the catchability coefficient determined by Fargo (1985) of 0.0000835, the fishing mortality (F) for the stock in 1989 was 0.28 ($F=Qe_t$). This value is slightly higher than the $F_{0.1}$ level (0.23), and M (0.21) for the species.

4.5.1.12. Yield Options

Low risk-sustainable yield option -- The fishery in 1989 was operating slightly above the $F_{0.1}$ level, with removals of about 1000 t. Yields of 800 t (equivalent to $F_{0.1}$ yield) should minimize the risk of overfishing at the present time. The 30,000 lb. coastwide trip limit is consistent with this option.

High risk-sustainable yield option -- The results from previous yield-per-recruit analysis (Fargo 1990), indicate that yields of 1000 t may be sustainable in the short-term with this strong recruitment mode. Yields this high also constitute a greater risk of overfishing for the stock.

4.5.2. English Sole -- Hecate Strait

4.5.2.1. Introduction

English sole in Hecate Strait have been treated as a single stock for this assessment. Standardized landing statistics, analysis of size composition data and yield-per-recruit analysis are the basis for this assessment.

4.5.2.2. The Fishery

The principal fishing grounds for English sole are Two Peaks-Butterworth (April-September) and White Rocks (October-March). Fishery production for the species is dependent upon recruitment, with recruitment being highly variable (coefficient of variation = 100%) over time. Approximately 80% of the landings come from Two Peaks-Butterworth. Most of the catch of this species is incidental to those of Pacific cod, which occupies similar depth ranges and areas. The majority of the harvest is composed of females aged 4-10 years (most males do not even attain legal 'commercial' size). The industry has imposed a size limit of about 35 cm based on a cost/recovery factor. The length of 50% maturity for the species, often used as a biological basis for minimum size regulations, is about 30 cm.

4.5.2.3. Landing Statistics

Landing statistics for English sole in Hecate Strait have been standardized following procedures outlined in Sec. 4.0.1. They are presented in Table 4.10 and Figs. 4.18-4.19 Landings of English sole in 1989 were 826 t, up from 688 t in 1988. Effort decreased to 1291 h in 1989, from 1313 h in 1988, probably as a result of the fishery for Pacific cod being less intensive in 1989 than in 1988. CPUE for 1989 was 640 kg/h, up from 524 kg/h in 1988, and the highest recorded for the 1956-89 time series. CPUE shows no long-term trend, while short-term trends coincide with recruitment fluctuations for the species. There has been an increasing trend in CPUE since 1985.

4.5.2.4. General Biological Information

The length frequency anomaly time series for Hecate Strait English sole (Fargo 1988) has been updated with 1987-89 samples (Figure 4.20). The anomalies indicate that recruitment is now above average with a significant increase occurring in 1987. This year-class is now contributing significantly to the fishery.

A summary of the catch-at-age data used in last year's virtual population analysis and yield simulations for English sole is contained in Table 4.11. This was inadvertently omitted from the 1989 assessment.

4.5.2.5 Yield per Recruit Analysis

Results from yield per recruit analysis in last year's assessment (Fargo 1990) indicated that a yield of 239 grams/recruit is achieved with a fishing rate of 0.21 (equivalent to $F_{0.1}$ and roughly equivalent to M for the species), with the current age of recruitment (age 3). Recruitment at above average levels in the past has been estimated from virtual population analysis to be 2,000,000 - 3,000,000 females. Sustainable yield for this level of recruitment is estimated to range between 700 t and 1000 t (assuming that females comprise 70% of the weight of individuals caught in the fishery). As stated in last year's assessment, yield could be increased by 30% if the age of recruitment for this stock was 4 rather than 3.

4.5.2.6. Condition of the Stock

On the basis of trends in CPUE in recent years and size composition data, the Hecate Strait English sole stock is considered to be at an above average level and increasing due to increasing recruitment. The age of recruitment, however, is below the age where maximum yield was obtained in yield per recruit analysis and yield simulations (Fargo 1990).Using the catchability coefficient for the stock determined by Fargo (1985) of 0.000183, the Fishing mortality for the stock in 1989 is 0.24 ($F=qE_t$), close to the $F_{0.1}$ level (0.21), and roughly equivalent to M (0.22) for the stock.

4.5.2.7. Yield Options

Low risk-sustainable yield option -- Yields of 700 t are sustainable with recruitment at high levels. As a caveat, this figure could be increased to 900 t if the age of recruitment could be increased to age 4, for example, by regulating mesh size.

High risk-sustainable yield option -- Yields up to 1000 t have been sustained in the past with recruitment at high levels, though the risk of overfishing is increased with removals this high.

4.5.3. Dover Sole

4.5.3.1. Introduction

The last detailed stock assessment for Dover sole is contained in Fargo (1990). As in the past, estimates of yield for this assessment are determined by surplus production analysis of standardized catch/effort data.

4.5.3.2. The Fishery

The fishery for Dover sole takes place at depths of 50-80 fathoms at Butterworth, Two Peaks, and Dundas grounds in northern Hecate Strait (May-October) and 100-200 fathoms at Langara Deep and Frederick Island (December-April) off the west coast of the Queen Charlotte Islands. The seasonal shift in the fishery is related to the annual spawning migration of the species.

4.5.3.3. Landing Statistics

Standardized landing statistics for Dover sole for 1970-89 are presented in Table 4.12 and Figs. 4.21-4.22. CPUE for Dover sole was standardized using the procedure outlined in Section 4.0.1. Landings in 1989 increased to 696 t from 649 t in 1988. Effort decreased to 1031 h in 1989 from 1346 h in 1988, and is below average for the period 1970-89. CPUE in 1989 increased to 675 kg/h from 482 kg/h in 1988. An increasing trend in CPUE has been apparent since 1980.

4.5.3.4. General Biological Information

Size composition data for 1989 indicate no change in mean length and in the overall size composition since the early 1970s.

4.5.3.5. Estimate of Fishing Mortality

Fishing mortality for Area 5C-E Dover sole was estimated using the following procedure. Size composition data for Area 5C-E Dover sole females for 1989 was compared to theoretical length frequencies produced from a simulation model developed by Rasmussen and Stanley (1988). The following growth parameter estimates were used for the simulations. They were calculated from length/age composition data for Area 5C-E Dover sole females (Fargo et al. 1985).

von Bertalanffy growth parameters:	L_∞ - 57.4 cm
	k - 0.12
	t_0 - -3.96
Instantaneous rate of natural mortality:	M - 0.15

Simulation results were compared with the 1989 size composition for female Dover sole in Area 5C-E. Observation of the right hand (descending) limb for simulated and sample length frequencies (Figure 4.23.) indicates that the Area 5C-E Dover sole stock has sustained a fishing mortality (F) of less than 0.10, 50% less than the instantaneous rate of natural mortality (M) for the species.

4.5.3.6. Condition of the Stock

The trend in CPUE from 1985-89 indicates that the abundance level of the stock of 5C-E Dover sole has not been adversely affected by average annual removals of about 800t . MSY estimated from standardized effort and CPUE using Gulland's (1961) method is 829 t, while the optimum effort level is estimated at 1315 h, using a lag period of 3 years.

4.5.3.6. Yield Options

Low risk-sustainable option -- Yields of 800 t are sustainable for the Area 5CDE Dover sole stock.

High risk-sustainable option -- Length frequency simulation results suggest that this stock could sustain much higher yields than the surplus production model indicates. A yield 1200 t (50% greater than the MSY landings) could be sustainable. The risk of overfishing is increased with yields at this level.

Table 4.1. Yield options for British Columbia flatfish species/stocks assessed in 1989-90.

		1989		1990	
Species	Area	low risk sustainable	high risk sustainable	low risk sustainable	high risk sustainable
Petrale sole	Coastwide	40,000 lb. trip limit	Free Fishery	40,000 lb. trip limit	Free Fishery
Dover sole	Area 3C-D	1000 t	2000 t	500 t	2000 t
	Area 5CDE	800 t	1000 t	800 t	1200 t
Rock sole	Area 5A	100 t	250 t	250 t	500 t
	Area 5B	200 t	400 t	250 t	600 t
	Area 5C	250 t	600 t	100 t	400 t
	Area 5D	700 t	1000 t	800 t	1000 t
English sole	Area 5CD	700 t	800 t	700 t	1000 t

Table 4.2. Canada-U.S. landings (t) of petrale sole from southwest Vancouver Island (Area 3C)--the area occupied by the "southern stock" 1942-89.

Year	Flattery Spit	Northern section Area 3C	Total Area 3C	Year	Flattery Spit	Northern section Area 3C	Total Area 3C
1942	n/d	-	1561	1966	118	512	630
1943	n/d	-	2264	1967	106	259	365
1944	n/d	-	1489	1968	114	233	347
1945	n/d	-	718	1969	255	142	397
1946	n/d	-	906	1970	80	198	278
1947	n/d	-	627	1971	74	523	597
1948	n/d	-	1321	1972	22	561	583
1949	n/d	-	1178	1973	211	452	663
1950	n/d	-	854	1974	230	684	914
1951	n/d	-	794	1975	474	465	939
1952	n/d	-	948	1976	304	453	757
1953	n/d	-	748	1977	157	311	468
1954	n/d	-	664	1978	287	126	413
1955	n/d	-	415	1979	256	92	348
1956	40	585	625	1980	147	115	262
1957	9	629	638	1981	125	180	305
1958	19	609	628	1982	45	232	277
1959	33	1072	1105	1983	179	183	362
1960	233	974	1207	1984	237	218	455
1961	375	1109	1484	1985	122	147	269
1962	215	850	1065	1986	75	197	272
1963	90	658	748	1987	113	123	236
1964	71	530	601	1988	182	183	365
1965	140	658	798	1989	192	386	588

n/d = no data available.

Table 4.3. Canada-U.S. landings (t) of petrale sole from the "northern stock" Areas 3D,5A-5D, 1942-89.

Year	Area 3D	Areas 5A-5B	Areas 5C-5D	Total	Year	Area 3D	Areas 5A-5B	Areas 5C-5D	Total
1942	-	-	-	-	1966	264	469	260	993
1943	-	-	-	-	1967	169	485	176	830
1944	499	303	-	802	1968	293	266	137	696
1945	270	1535	193	1998	1969	262	114	22	398
1946	623	1258	494	2375	1970	136	56	22	214
1947	469	986	769	2224	1971	127	97	55	280
1948	943	920	3011	4874	1972	50	154	33	237
1949	316	429	1644	2390	1973	197	211	24	432
1950	694	569	700	1963	1974	196	283	14	493
1951	305	326	642	1273	1975	234	156	27	417
1952	265	305	574	1144	1976	153	132	30	315
1953	235	450	46	731	1977	58	73	24	155
1954	712	234	300	1237	1978	21	63	13	97
1955	452	462	94	1008	1979	10	57	39	106
1956	291	528	53	872	1980	31	40	33	104
1957	1320	333	216	1869	1981	15	41	42	98
1958	174	227	171	572	1982	30	61	16	107
1959	227	160	216	603	1983	29	161	35	225
1960	93	212	120	425	1984	77	79	24	180
1961	277	171	102	550	1985	50	81	22	153
1962	295	343	165	803	1986	24	120	25	169
1963	202	537	82	821	1987	37	165	101	303
1964	183	421	163	767	1988	276	167	133	576
1965	300	418	202	920	1989	178	220	151	549

Table 4.4. Canadian landing statistics for Dover sole in Areas 3C-D, 1980-89.

Year	Landings (t)	Effort (h)[a]	CPUE (kg/h)[b]
1980	277	415	667
1981	255	606	421
1982	200	476	420
1983	98	316	310
1984	99	176	563
1985	76	43	1750
1986	77	33	2355
1987	38	185	205
1988	514	905	568
1989	1328	2334	569
1990[c]	1300	1813	717

[a] Effort = (Landings X 1000)/CPUE
[b] CPUE = Area 3CD - 25% qualified
[c] Preliminary figures

Table 4.5. Standardized Canada-U.S. landing statistics for rock sole in Area 5A, 1956-89.

Year	Landings (t)	Effort (h)[a]	CPUE (kg/h)[b]
1956	551	2688	205
1957	511	2344	218
1958	501	2913	172
1959	212	981	216
1960	397	2181	182
1961	237	1215	195
1962	196	1248	157
1963	161	925	174
1964	156	757	206
1965	157	671	234
1966	330	1341	246
1967	252	1100	229
1968	435	1576	276
1969	293	1966	149
1970	167	807	207
1971	135	763	177
1972	58	360	161
1973	57	298	191
1974	74	679	109
1975	37	264	140
1976	182	1422	128
1977	83	580	143
1978	79	537	147
1979	202	863	234
1980	238	933	255
1981	114	606	188
1982	189	784	241
1983	124	660	188
1984	142	768	185
1985	56	452	124
1986	23	338	68
1987	80	468	171
1988	128	842	152
1989	143	777	184

[a] Effort = (Landings X 1000)/CPUE.

[b] CPUE = Area 5A, April-September standardized by log-linear model (See Section 4.0.1.).

Table 4.6. Standardized Canada-U.S. landing statistics for rock sole in Area 5B, 1956-89.

Year	Landings(t)	Effort (h)[a]	CPUE (kg/h)[b]
1956	307	1263	243
1957	206	963	214
1958	379	1905	199
1959	344	1670	206
1960	503	2430	207
1961	416	2447	170
1962	531	2529	210
1963	517	2559	202
1964	482	2161	223
1965	568	2459	231
1966	772	3051	253
1967	741	3062	242
1968	392	2042	192
1969	652	3663	178
1970	245	1283	191
1971	368	1887	195
1972	382	1873	204
1973	324	1742	186
1974	371	1742	213
1975	408	2125	192
1976	368	2079	177
1977	188	1306	144
1978	217	1102	197
1979	208	1284	162
1980	410	1723	238
1981	220	1134	194
1982	155	994	156
1983	206	1056	195
1984	87	551	158
1985	170	1024	166
1986	135	714	189
1987	205	891	230
1988	272	1106	246
1989	260	1156	225

[a] Effort = (Landings X 1000)/CPUE.

[b] CPUE = Area 5B, April-September standardized by log-linear model (See Section 4.0.1.)

Table 4.7. Standardized Canada-U.S. landing statistics for rock sole in Area 5C, 1956-89.

Year	Landings	Effort (h)[a]	CPUE (kg/h)[b]
1956	397	794	500
1957	726	2305	315
1958	368	814	452
1959	249	616	404
1960	471	1066	442
1961	110	345	319
1962	322	638	505
1963	155	408	380
1964	244	528	462
1965	539	1485	363
1966	961	2355	408
1967	948	1615	587
1968	811	1959	414
1969	1053	3510	300
1970	694	2810	247
1971	376	1614	233
1972	134	439	305
1973	186	514	362
1974	288	766	376
1975	383	1178	325
1976	277	745	372
1977	272	829	328
1978	356	1319	270
1979	647	1668	388
1980	482	1511	319
1981	126	457	276
1982	70	326	215
1983	60	210	286
1984	64	149	430
1985	28	92	303
1986	86	497	173
1987	209	496	421
1988	189	545	347
1989	406	1476	275

[a] Effort = (Landings X 1000)/CPUE.

[b] CPUE = Area 5C, April-September standardized by log-linear model (See Section 4.0.1.).

Table 4.8. Standardized Canada-U.S. landing statistics for rock sole in Area 5D, 1956-89.

Year	Landings(t)	Effort (h)[a]	CPUE (kg/h)[b]
1956	763	2764	276
1957	425	1296	328
1958	888	1170	759
1959	167	283	590
1960	656	881	745
1961	634	854	742
1962	507	762	665
1963	726	1177	617
1964	499	1082	461
1965	340	837	406
1966	1583	3251	487
1967	1214	1243	977
1968	1555	4307	361
1969	1356	2751	493
1970	709	2091	339
1971	1127	3601	313
1972	381	1432	266
1973	321	915	351
1974	334	633	528
1975	821	1808	454
1976	1161	3617	321
1977	574	2382	241
1978	518	1537	337
1979	666	2313	288
1980	495	1612	307
1981	458	1900	241
1982	221	925	239
1983	187	776	241
1984	124	653	190
1985	84	661	127
1986	133	573	232
1987	327	678	482
1988	1213	5274	230
1989	1016	3398	299

[a] Effort = (Landings X 1000)/CPUE.

[b] CPUE = Two Peaks-Butterworth, April-September standardized by log-linear model (See Section 4.0.1.).

Table 4.9. Catch-at-age data (thousands of fish) for female rock sole in Area 5D for the commercial trawl fishery, 1946-85.

	Age								
Year	4	5	6	7	8	9	10	11	12
1945	8	12	14	23	28	14	7	3	1
1946	146	53	30	40	34	23	12	4	2
1947	518	389	69	42	56	22	18	9	4
1948	146	472	140	60	31	34	10	4	1
1949	29	160	206	56	26	19	9	3	2
1950	69	90	151	186	41	19	5	3	1
1951	509	413	170	94	94	27	3	4	0
1952	709	872	253	115	73	26	8	1	1
1953	14	89	185	86	31	15	6	3	1
1954	81	358	253	89	27	10	3	4	1
1955	21	264	436	280	128	49	28	13	7
1956	58	78	164	147	89	49	16	5	4
1957	46	44	88	88	66	37	22	10	2
1958	44	743	149	68	34	41	10	8	2
1959	2	133	101	16	3	2	2	0	0
1960	10	332	508	92	24	9	3	2	3
1961	0	45	498	361	66	5	5	0	0
1962	0	6	91	298	124	23	10	1	0
1963	29	63	98	228	206	78	24	4	5
1964	105	116	60	90	107	44	11	6	1
1965	48	114	86	64	61	29	12	7	2
1966	75	729	661	304	197	121	75	46	18
1967	39	414	354	354	115	53	19	12	2
1968	205	391	671	216	55	24	12	5	0
1969	441	362	245	138	29	11	4	0	0
1970	9	117	247	262	79	82	24	20	2
1971	21	229	365	181	154	74	18	3	0
1972	55	58	74	47	39	21	6	5	2
1973	48	30	20	27	21	12	7	7	4
1974	152	180	13	2	0	6	6	2	0
1975	23	72	223	228	168	96	41	12	5
1976	94	154	267	76	28	12	0	0	0
1977	82	165	112	81	19	8	4	3	3
1978	124	108	82	72	52	33	32	15	11
1979	43	150	156	65	53	22	32	26	6
1980	357	131	69	9	5	0	0	0	0
1981	158	63	43	110	102	38	18	14	11
1982	0	3	11	66	73	35	17	14	11
1983	2	13	35	50	28	20	3	2	3
1984	7	12	17	27	42	8	12	3	3
1985	3	3	9	12	12	20	9	6	3

Table 4.10. Standardized Canada-U.S. landing statistics for English sole in Hecate Strait, 1956-89.

Year	Landings	Effort (h)[a]	CPUE (kg/h)[b]
1956	956	1777	538
1957	552	1246	443
1958	693	1383	501
1959	940	1850	508
1960	1147	1868	614
1961	871	1407	619
1962	459	863	532
1963	408	940	434
1964	436	946	461
1965	414	1128	367
1966	362	761	476
1967	534	837	638
1968	671	1504	446
1969	819	1635	501
1970	1002	2288	438
1971	488	1564	312
1972	371	845	439
1973	667	1310	509
1974	500	778	643
1975	938	1793	523
1976	1133	2989	379
1977	1179	3062	385
1978	559	1463	382
1979	864	2413	358
1980	995	2282	436
1981	1327	3676	361
1982	428	1209	354
1983	430	1044	412
1984	658	1449	454
1985	585	1789	327
1986	335	786	426
1987	630	1005	627
1988	688	1313	524
1989	826	1291	640

[a] Effort = (Landings X 1000)/CPUE.

[b] CPUE = Two Peaks-Butterworth, April-September, Standardized by log-linear model (See Section 4.0.1).

Table 4.11. Catch-at-age data (in thousands of fish) for female English sole caught in the commercial trawl fishery in Hecate Strait, 1955-79.

	Age									
Year	3	4	5	6	7	8	9	10	11	12
1955	27	374	403	244	157	123	72	34	11	7
1956	16	216	614	317	160	87	34	12	12	10
1957	12	173	143	249	126	57	24	22	12	0
1958	6	116	259	218	224	103	53	36	11	3
1959	9	253	455	350	215	135	71	32	21	6
1960	40	377	519	386	246	273	88	33	17	10
1961	2	268	650	309	138	69	41	19	12	4
1962	6	136	308	160	94	30	11	11	4	0
1963	8	102	194	225	76	33	8	7	0	2
1964	17	218	280	132	66	29	5	5	1	1
1965	1	99	246	188	103	48	21	12	2	2
1966	2	86	208	187	97	42	17	8	0	1
1967	3	57	405	316	123	57	24	9	5	1
1968	9	28	170	481	226	96	35	2	2	0
1969	32	79	121	220	405	149	48	17	0	3
1970	51	234	158	126	200	232	77	28	4	0
1971	31	253	137	49	51	55	66	25	8	3
1972	92	175	157	67	39	36	39	17	8	1
1973	162	204	246	113	49	38	35	18	11	0
1974	66	187	167	116	82	36	25	6	7	10
1975	35	277	391	286	200	102	60	9	10	2
1976	15	157	463	372	242	122	69	13	0	4
1977	112	288	398	282	176	79	46	7	11	0
1978	31	88	138	81	59	47	33	8	0	0
1979	122	232	255	157	113	81	56	8	10	2

Table 4.12. Standardized Canada-U.S. landing statistics for Dover sole, Areas 5C,D,E, 1970-89.

Year	Landings(t)	Effort (h)[a]	CPUE (kg/h)[b]
1970	965	1260	766
1971	903	1244	726
1972	922	1297	711
1973	768	866	887
1974	767	872	880
1975	882	1305	676
1976	1022	2069	494
1977	577	1568	368
1978	483	1495	323
1979	697	2020	345
1980	807	1747	462
1981	840	2039	412
1982	512	1438	356
1983	693	1372	505
1984	953	1749	545
1985	830	1697	489
1986	1040	1871	556
1987	503	708	710
1988	649	1346	482
1989	696	1031	675

[a] Effort = (Landings X 1000)/CPUE.
[b] CPUE = Dundas, June-September standardized by log-linear model (See Section 4.0.1.).

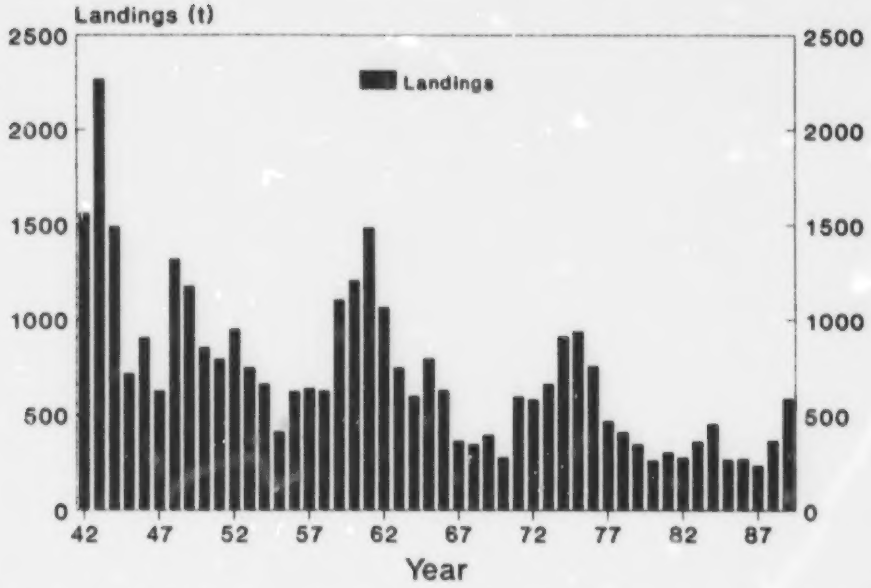


Fig. 4.1. Canada-U.S. landings of petrale sole from the 'southern' stock 1942-89.

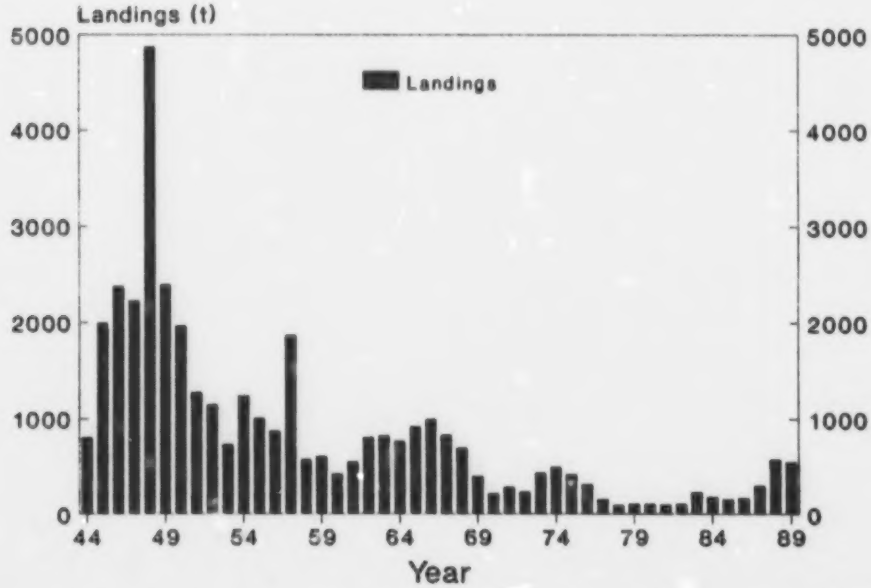


Fig. 4.2. Canada-U.S. landings of petrale sole from the 'northern' stock 1942-89.

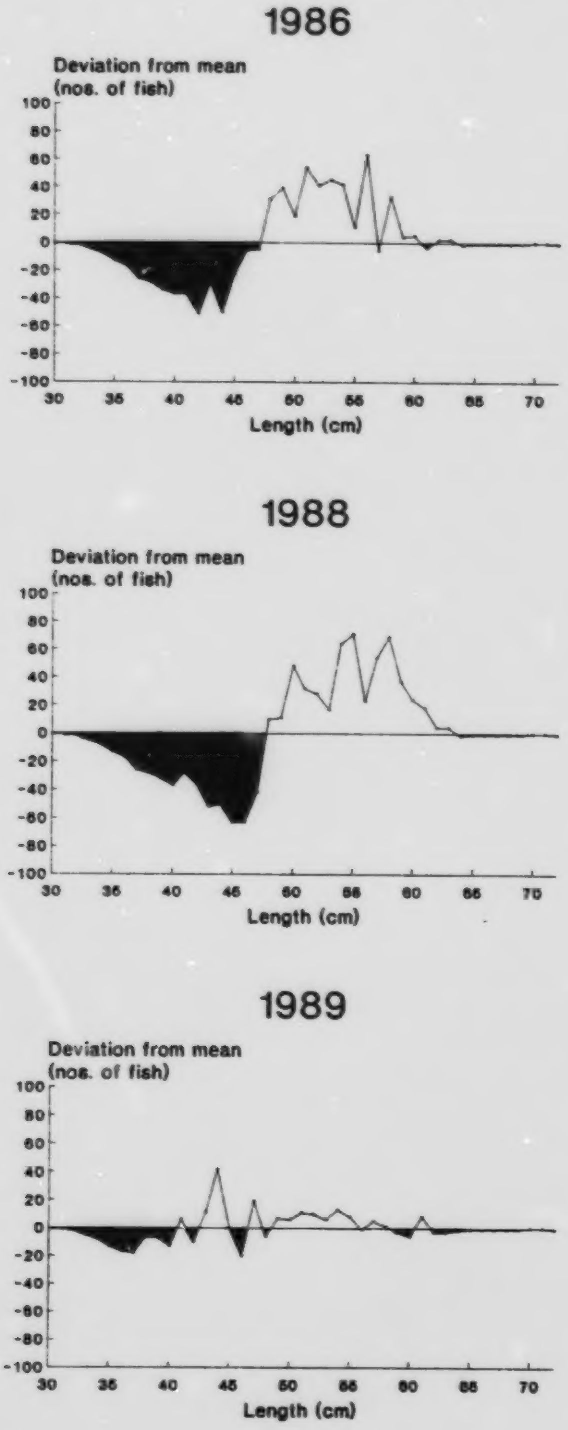


Fig. 4.3. Length frequency anomalies for the 'southern' stock of petrale sole based on port samples 1986-89.

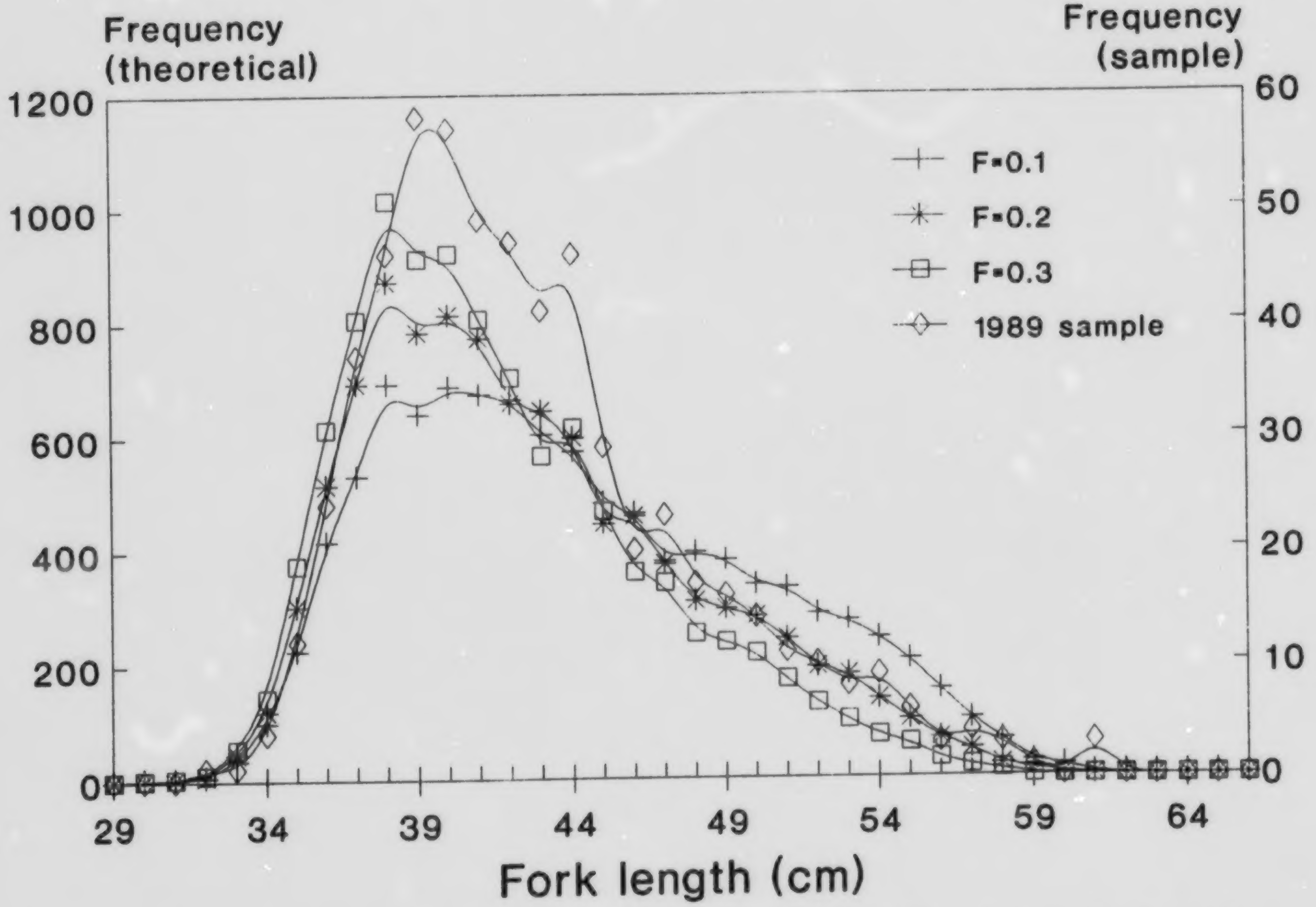


Fig. 4.4. Theoretical and observed length frequencies for petrale sole females from the 'southern' stock.

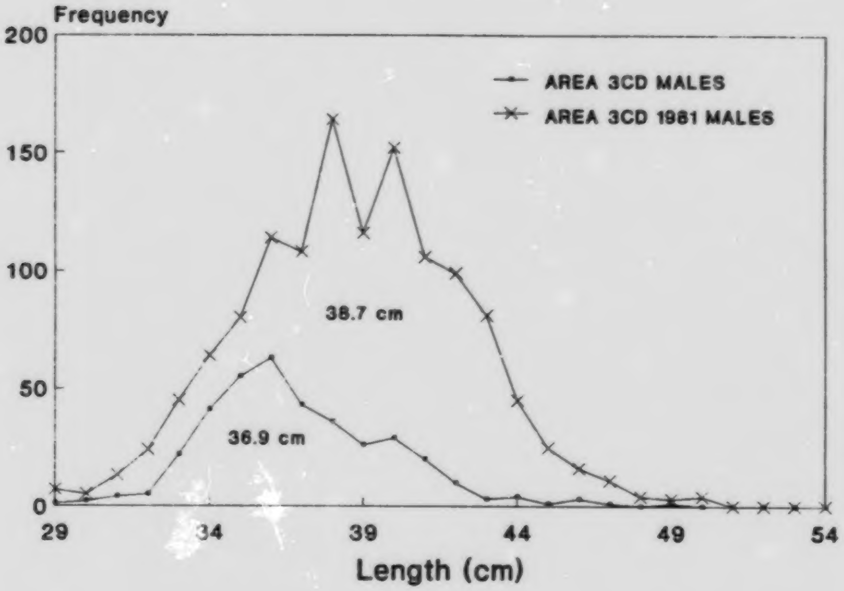


Fig. 4.5. Size composition for Area 3CD Dover sole males from port samples in 1989 and research samples in 1981.

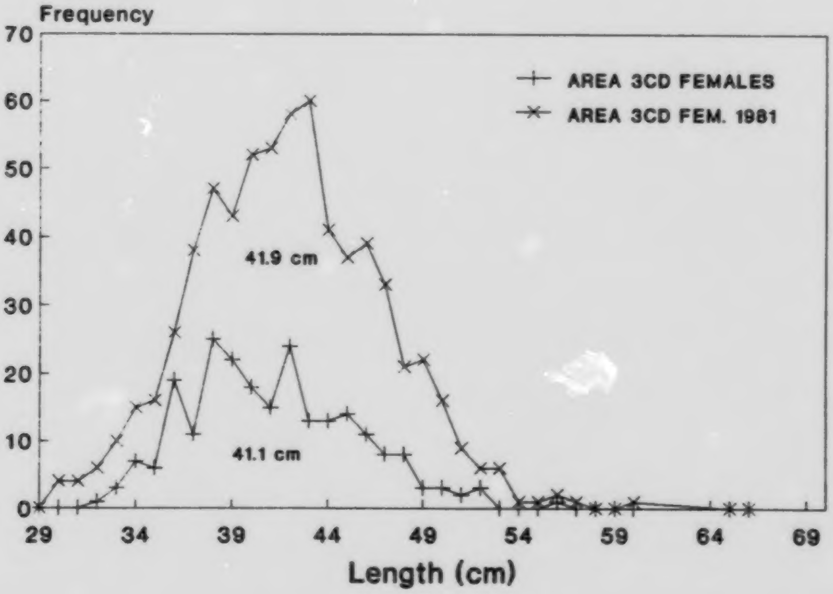


Fig. 4.6. Size composition for Area 3CD Dover sole females from port samples in 1989 and research samples in 1981.

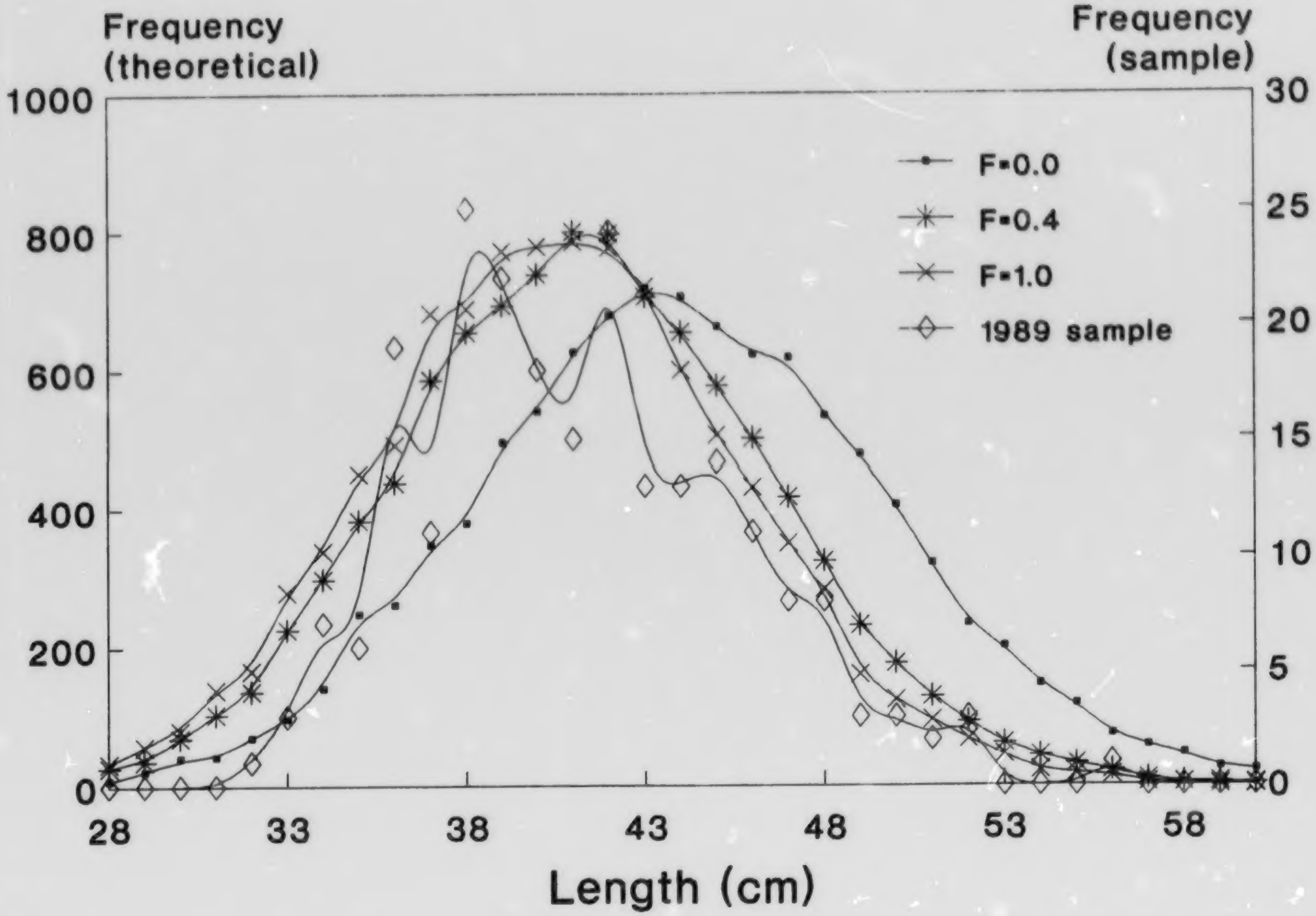


Fig. 4.7. Theoretical and observed length frequencies for Dover sole females from Area 3CD.

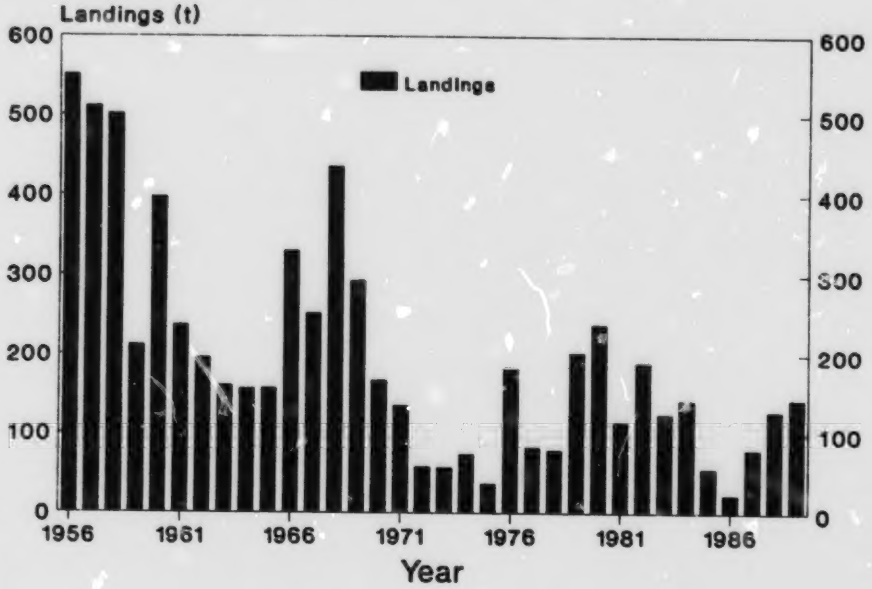


Fig. 4.8. Canada-U.S. landings for rock sole from Area 5A, 1956-89.

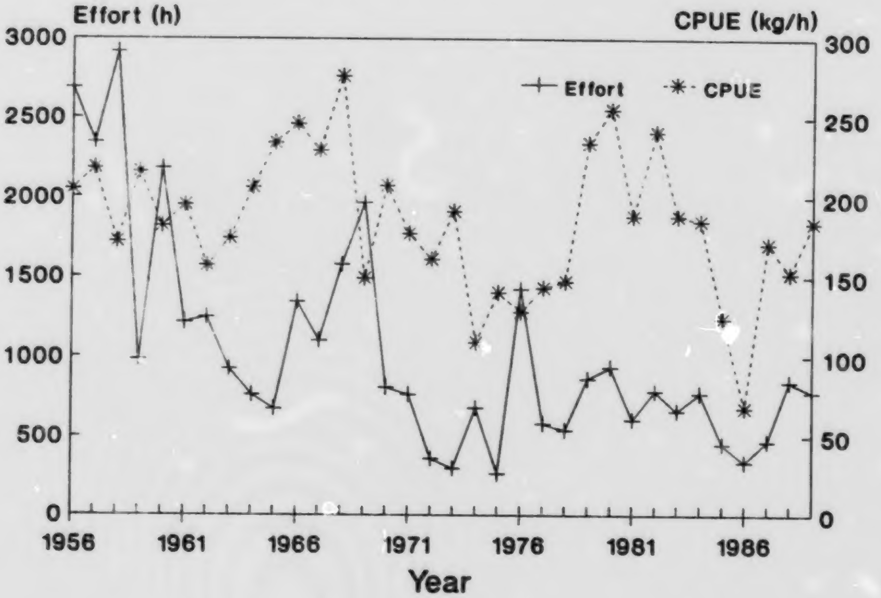


Fig. 4.9. Standardized effort and CPUE for rock sole from Area 5A, 1956-89.

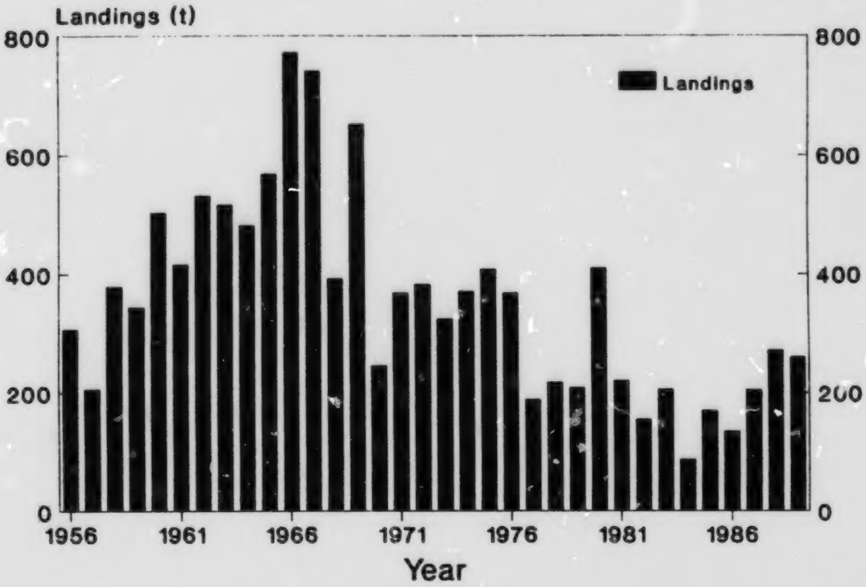


Fig. 4.10. Canada-U.S. landings for rock sole from Area 5B, 1956-89.

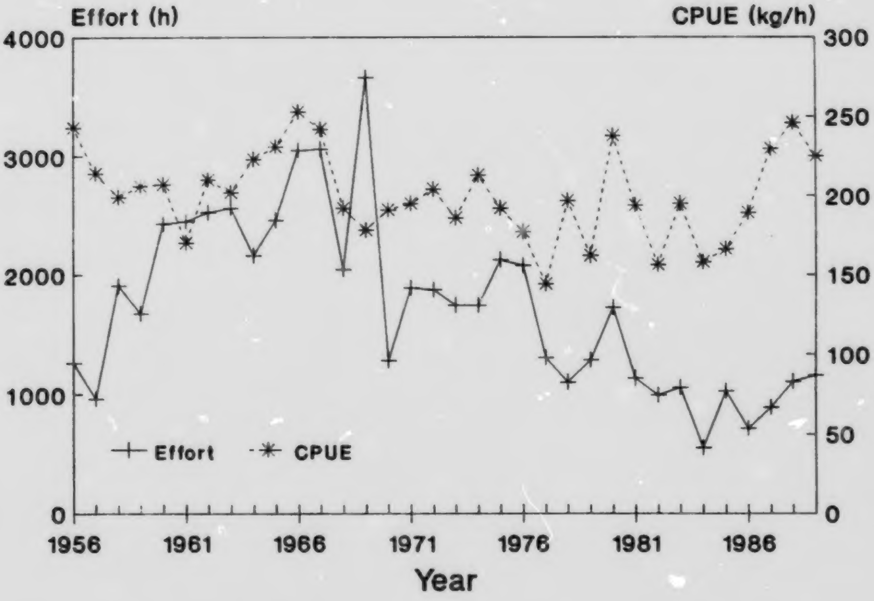


Fig. 4.11. Standardized effort and CPUE for rock sole from Area 5B, 1956-89.

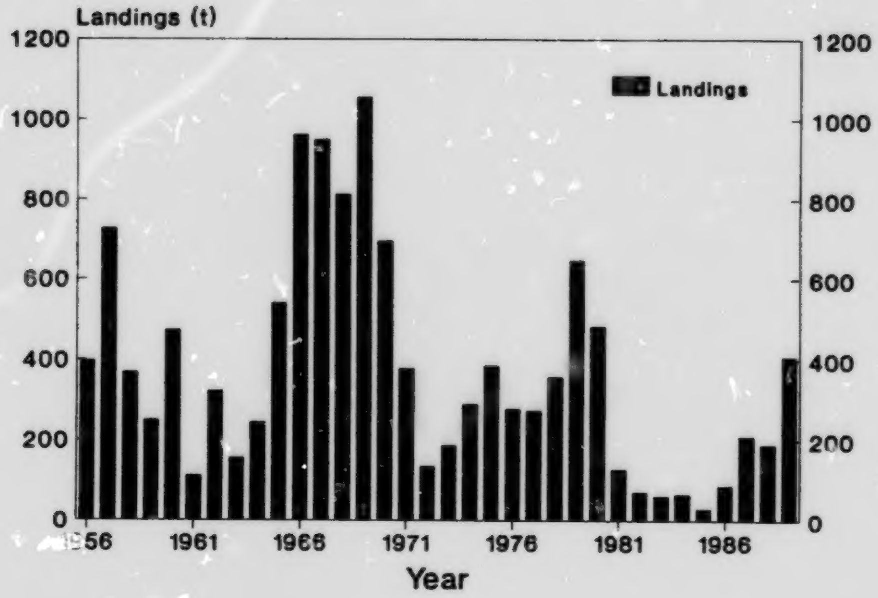


Fig. 4.12. Canada-U.S. landings for rock sole from Area 5C, 1956-89.

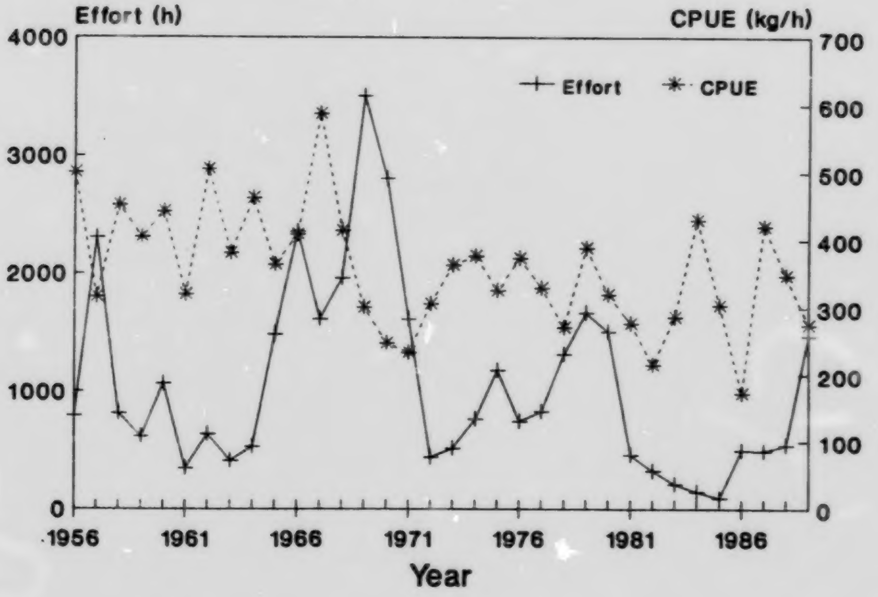


Fig. 4.13. Standardized effort and CPUE for rock sole from Area 5C, 1956-89.

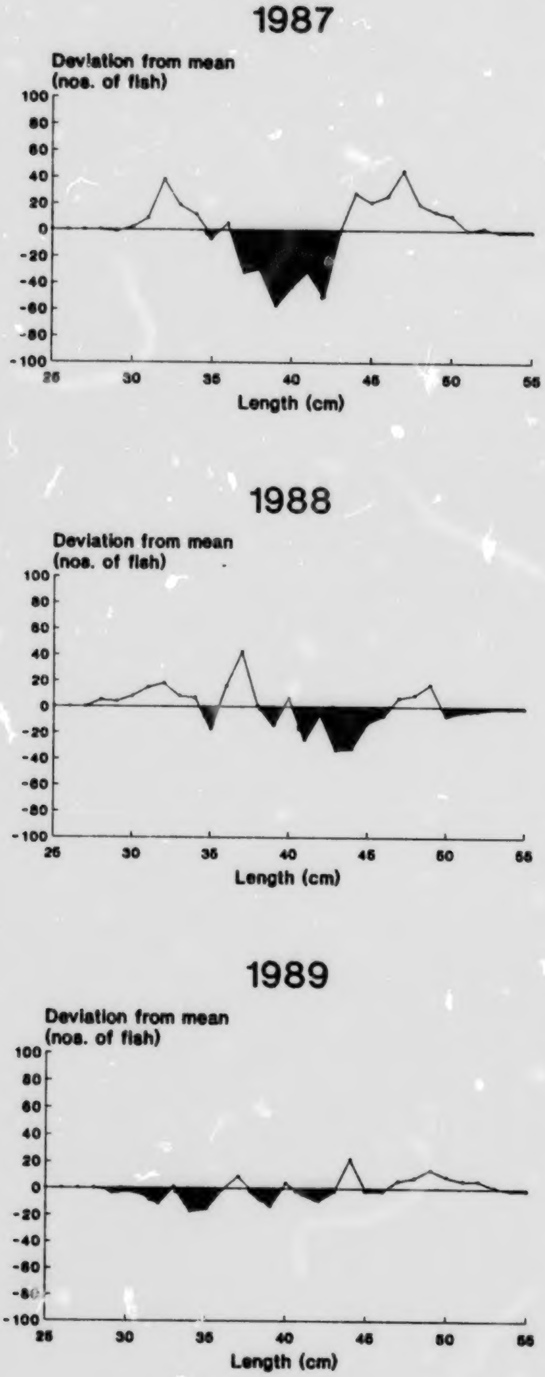


Fig. 4.14. Length frequency anomalies for rock sole from Area 5C, 1987-89.

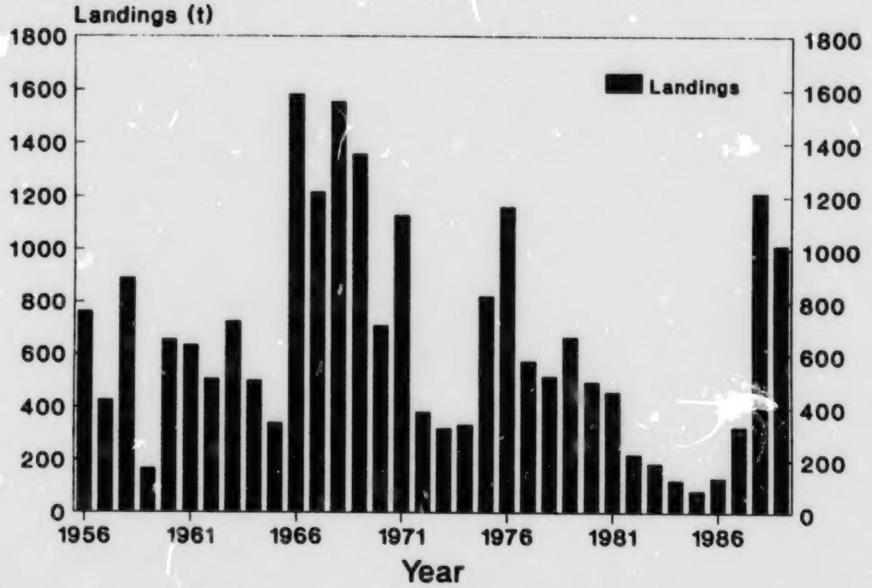


Fig. 4.15. Canada-U.S. landings for rock sole from Area 5D, 1956-89.

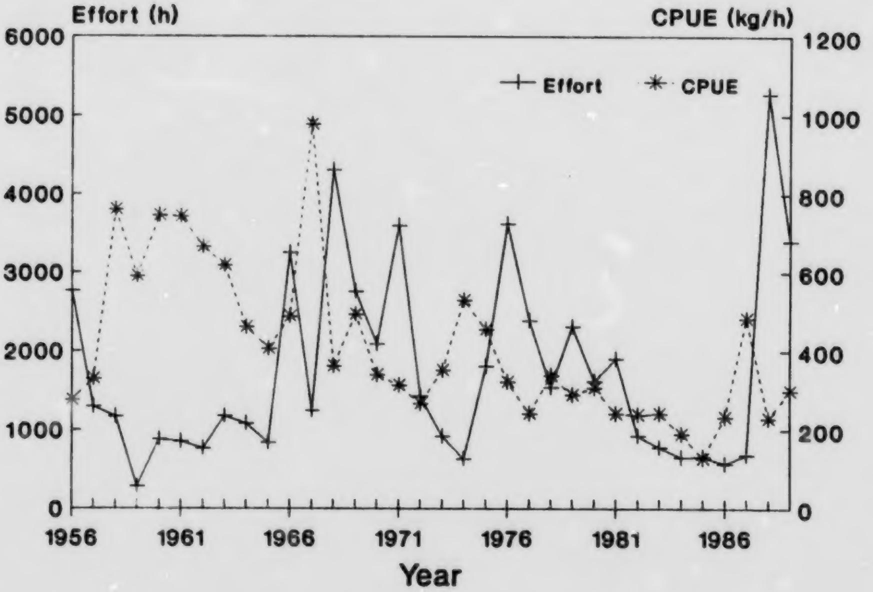


Fig. 4.16. Standardized effort and CPUE for rock sole from Area 5D, 1956-89.

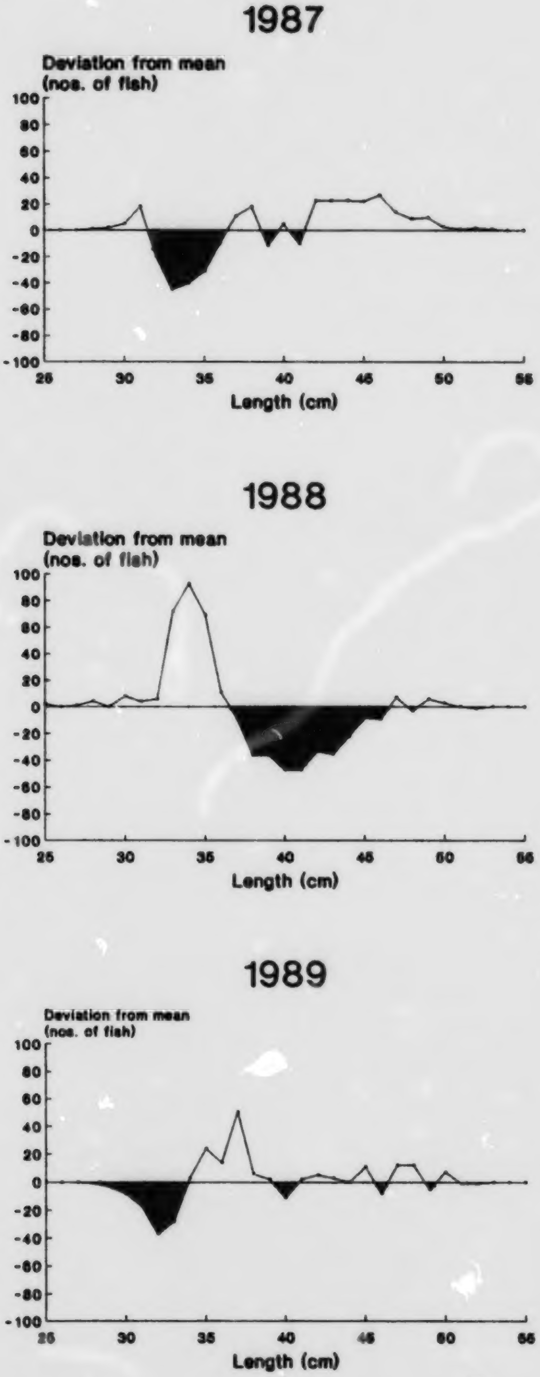


Fig. 4.17. Length frequency anomalies for rock sole from Area 5D, 1987-89.

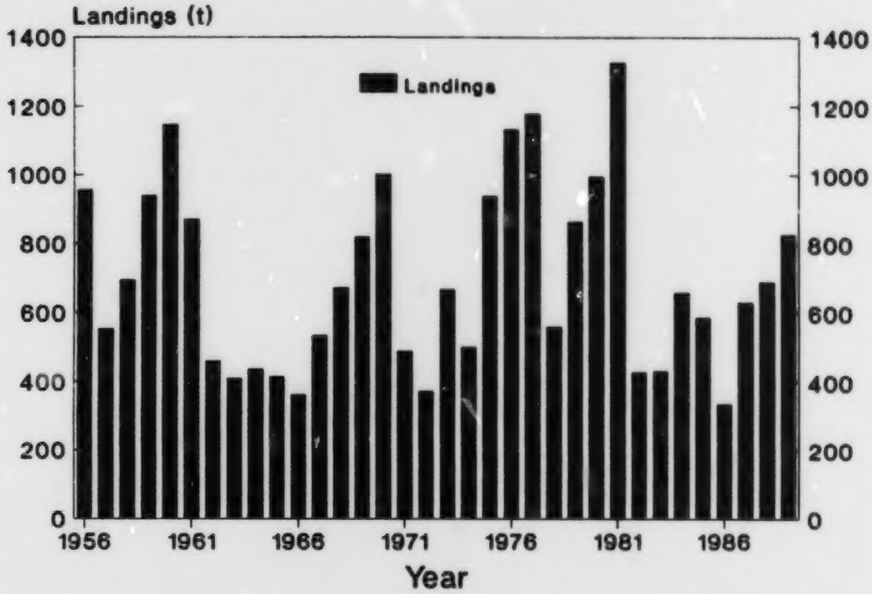


Fig. 4.18. Canada-U.S. landings for English sole from Hecate Strait (Areas 5C, D), 1956-89.

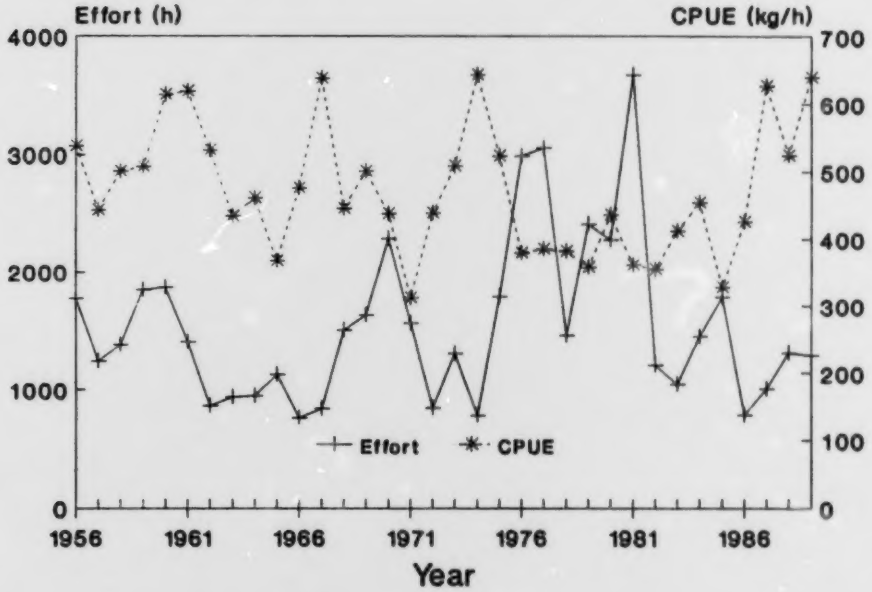


Fig. 4.19. Standardized effort and CPUE for English sole from Hecate Strait, 1956-89.

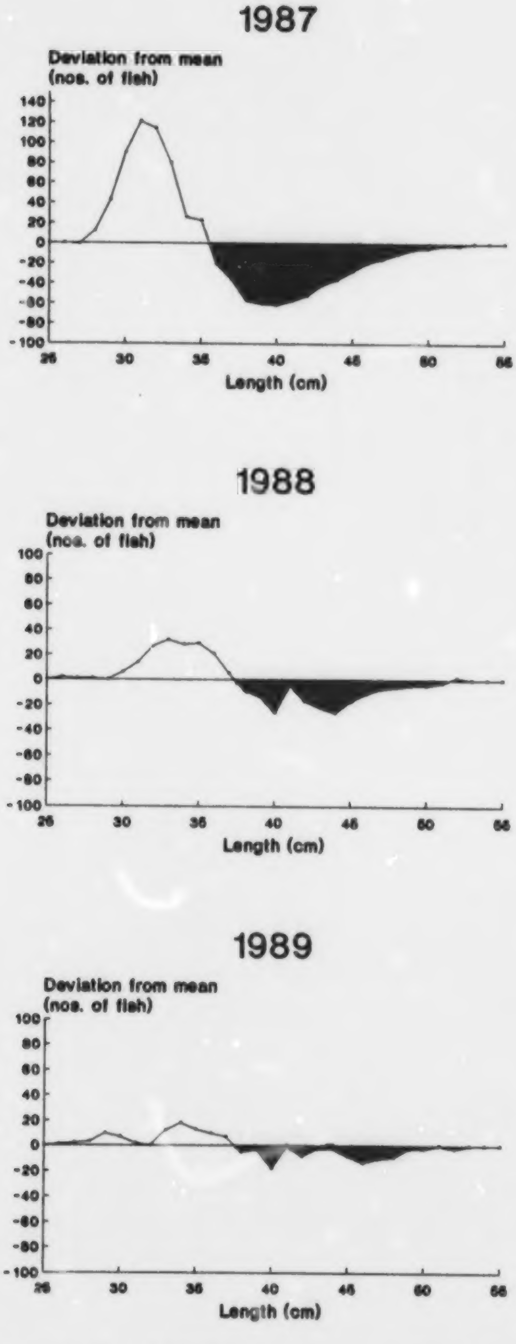


Fig. 4.20. Length frequency anomalies for English sole from Hecate Strait, 1987-89.

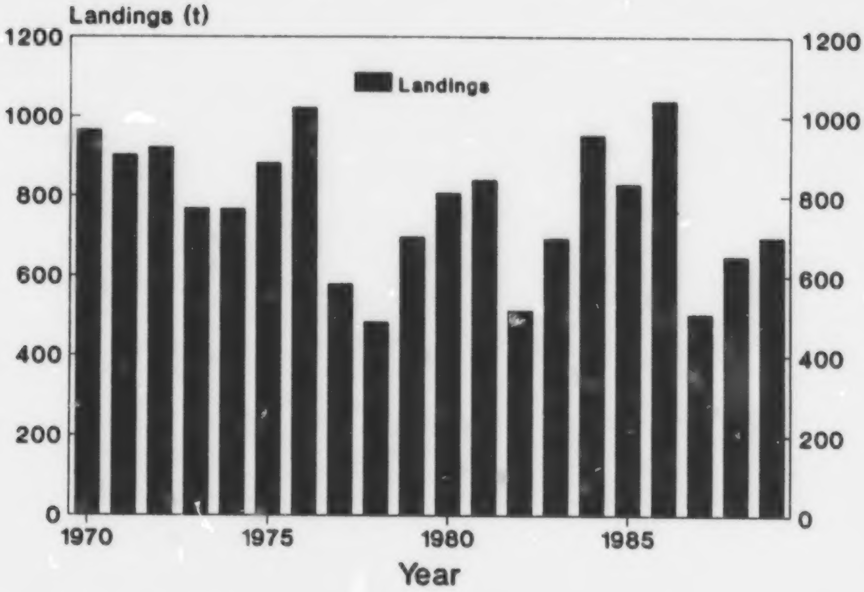


Fig. 4.21. Canada-U.S. landings for Dover sole from Areas 5CDE 1970-89.

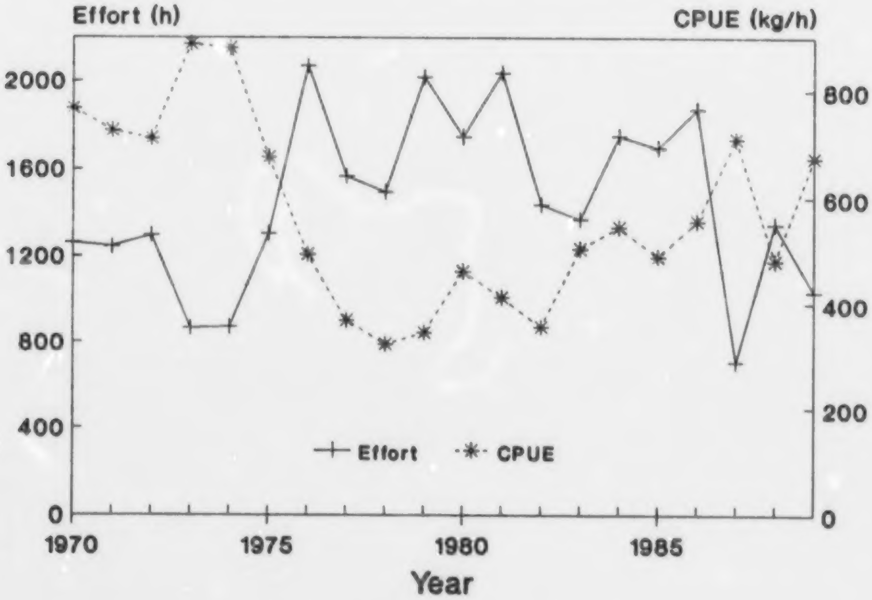


Fig. 4.22. Standardized effort and CPUE for Dover sole from Areas 5CDE 1970-89.

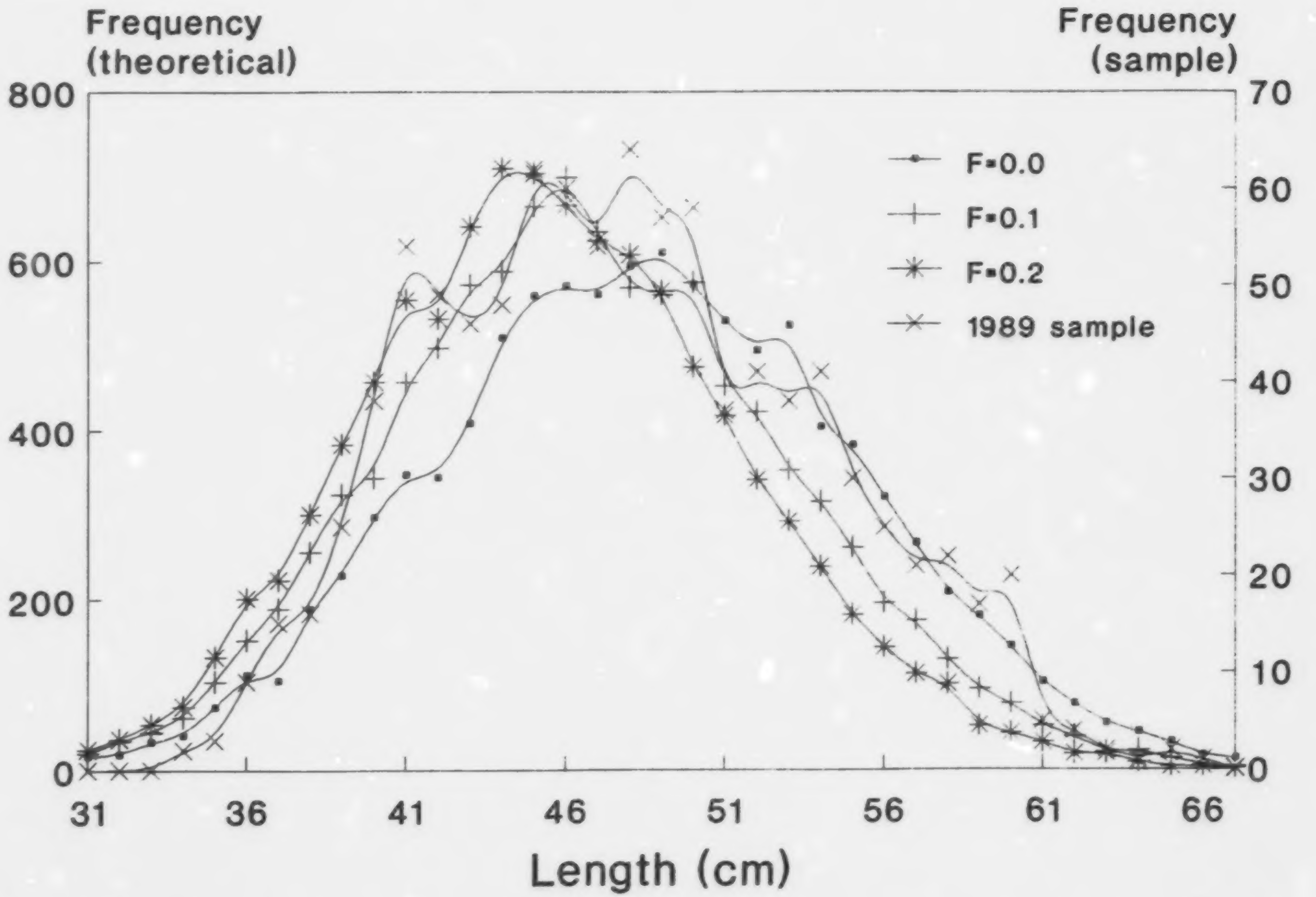


Fig. 4.23. Theoretical and observed length frequencies for Dover sole females from Area 5CDE.

5.0 SABLEFISH

by M. W. Saunders and G. A. McFarlane

5.1 Coastwide

5.1.2. Landing Statistics

In 1989, a total of 4893.5 t of sablefish were caught coastwide by trap, trawl, and longline. Nominal catch from the west coast of the Queen Charlotte Islands, Queen Charlotte Sound, and Hecate Strait decreased slightly from 2438.9 t in 1988 to 2372.1 t in 1989, with the majority (76.5%) caught by trap (Table 5.1).

Catch from the west coast of Vancouver Island decreased from 2778.1 t in 1988 to 2595.4 t in 1989. The largest proportion of fish were trap-caught (62.9%) (Table 5.2). The longline component had been increasing steadily since 1985, however, the percentage of longline caught sablefish dropped from 36.7% in 1988 to 20.5% in 1989. These fluctuations are to be expected as 'K' (Sablefish) licensed vessels are allowed to switch at will, between hook and trap/longline gear.

Trawl catch from the west coast of Vancouver Island decreased slightly from 454.0 t in 1988 to 430.4 t in 1989. Trawl landings from all other areas combined, increased to 257.7 t in 1989 from 176.7 t in 1988 (Tables 5.1 and 5.2).

5.1.3 General Biological Information

AGE DATA

In recent assessments (Saunders et al. 1989 and Saunders and McFarlane 1990), catch-at-age data indicate that the fishery is becoming increasingly dependant on younger fish (Figure 5.1). The cause of this age-frequency truncation could be the result of a number of factors. Most serious would be a fishing down of the older ages. If true, then the rapid loss of the older ages and the dependence of the fishery on 10-15 year-classes is cause for concern for a species with documented periods of low recruitment. There are, however a number of possible explanations that should be considered, especially if age-based assessment procedures continue to be used.

First of all, the increasing price for small fish (< 60 cm) since 1984 and the shorter duration of the fishery has led to more smaller, and potentially younger fish being retained and landed.

If recruitment in recent years has been high, then strong year-classes may simply be dominating the samples by number. Unfortunately effort data are not available to weight the samples to allow comparison among years.

It is also possible that the changes are an artifact of shifting effort patterns. We reported in last year's assessment that, the distribution of effort in the commercial fishery changed considerably over the period 1979 to 1984. However, since then, the distribution of effort by depth, (Figure 5.2) and the age frequencies have been consistent (Figure 5.1). During the years 1979 and 1980 a high proportion of the effort was directed at depths of 450 to 550 fm, while in recent years the majority of effort has been directed at depths of between 250 fm and 450 fm (Figure 5.2). If the abundance of a particular cohort varies with depth, i.e. older fish tending to be deeper, then the age frequency for a year when fishing is conducted at deeper depths, such as 1979, should be dominated by older fish.

To examine this question, the available ageing effort during 1989/90, has been focused on ageing a complete set of trap samples taken at discrete depth intervals from the 1986 and 1989 assessment surveys conducted during November of each year sampled. Most commercial and research samples can not be used to examine depth differences since trap strings are not set along a discrete depth but rather from shallow to deeper depths. Strings of trap gear were set within three depth strata, shallow (<300 fm), mid-depth (301-400 fm) and deep (>400 fm).

Preliminary results suggest that there are differences in the age distribution by depth. The age frequency of commercial samples taken in 1979, when fishing was conducted at depths greater than 450 fm is similar to age frequency of a sample taken from Barkley Canyon deep during the 1986 survey (Figure 5.3). A sample from Triangle Island (deep) contains a slightly higher proportion of older fish than the sample taken at mid-depth (Figure 5.4). If further work confirms these preliminary results then the catch-at-age analysis will have to be modified to account for changes in availability that may occur by changing effort patterns.

LENGTH DATA

Analysis of length frequencies from the 1986, 1988 and 1989 surveys is currently underway. The length frequencies of females by area for shallow and deep depth strata are presented in Figures 5.6a and 5.6b, respectively. During the 1989 survey mean lengths of males and females increased with increasing latitude. For example, the mean length of females caught at shallow depths ranged from 62.0 cm in Barkley Canyon to 77.1 cm off Langara Island (Figure 5.5a). There was little difference among depths at most stations. For example, off Gowgaia, the mean length at deep depths was 73.0 cm, while the mean length at shallow depths was 73.6 cm.

Length frequencies from stations that were occupied in all three years are consistent (Figure 5.7a and 5.7b), with the exception of Barkley Canyon (shallow), which shows a decrease in the frequency of fish greater than 75 cm.

5.1.4 Condition of the Stock

CPUE

In last year's assessment, (Saunders and McFarlane 1990) a method of standardizing effort was described and results presented (Table 5.3). During 1988 and 1989 there was a considerable increase in nominal and standardized CPUE. It was pointed out that the increase should be viewed with cautious optimism, since the timing of the increase in CPUE coincides with a drastic change in execution of the fishery. During 1988 and 1989 individuals from the 48-licence fleet were able to choose from monthly openings from February to September rather than the previous one or two openings per year.

Preliminary data for 1990 are unavailable. Even if they were available, the consistency with previous years in the time series would be poor due to the adoption of Individual Vessel Quota (IQ) management. For example vessel quota management has resulted in a shift in effort patterns, with fishermen applying effort to areas where by-catch of other species is higher. This allows fishermen to prolong their season, however, it will also tend to lower the estimates of sablefish CPUE.

CATCH-AT-AGE ANALYSIS

The catch-at-age analysis remains unchanged from the previous assessment (Saunders and McFarlane, 1989). The current model will be examined over the next year and be modified or replaced as need be to insure that the model is consistent with results of biological studies reported earlier.

Vessel quota management appears to be affecting our ability to assess the stock. The number of samples required to accurately sample the fishery given the multitude of time/area/depth windows is prohibitive. It follows that, without adequate sampling, a catch-at-age analysis may not be possible. In addition, the change in the fishery decreases the reliability of our CPUE data as an indicator of abundance.

As a result we are considering a number of assessment alternatives. One, is the development of a research survey to assess relative abundance of the stock. Present surveys have been used to collect biological samples and have not been developed to assess either relative or absolute abundance.

Secondly we are examining the possibility of using the data base of landings by weight category to develop a length or weight-based assessment model.

Overall, we feel that the stock is in good condition considering the stability in length frequencies by area and the rising CPUE.

5.1.5 Yield Options

The yield options remain unchanged from the previous year's assessment. The reader is referred to last year's document (Saunders and McFarlane 1990) for a detailed description of the catch-at-age analysis.

Risk in the yield options listed below is a function of the uncertainty regarding recruitment. There exists a strong possibility that the high-risk level may interfere with future yield. The high risk level is the mid-point between the F levels assuming high recruitment and high natural mortality. The low risk level is the mid-point between the F levels assuming average recruitment and low natural mortality. The sustainable level is the mid-point between the high and low risk levels.

Sustainable - low-risk -	2900 t
Sustainable -	4000 t
Sustainable - high-risk -	5000 t

Table 5.1. Canadian sablefish nominal catch, by gear, from Queen Charlotte Sound, Hecate Strait, and the west coast of the Queen Charlotte Islands, 1973-1989 (Major Areas 5A, 5B, 5C, 5D and 5E) (round wt, metric tonnes)[a], excluding dumped and discarded fish.

	Gear type								
	Longline		Trawl		Trap		Other[b]		
Year	Wt	%[c]	Wt	%	Wt	%	Wt	%	Total
1973	116.6	21.6	31.7	5.9	392.4	72.6	-	-	540.7
1974	39.0	16.1	38.1	15.7	165.6	68.2	-	-	242.7
1975	149.9	22.7	82.0	12.4	427.9	64.9	-	-	659.8
1976	47.7	10.4	154.2	33.7	255.8	55.9	-	-	457.7
1977	49.8	16.9	98.3	33.4	145.7	49.4	.9	.3	294.7
1978	39.0	8.2	40.4	8.5	395.1	83.0	1.4	.3	475.9
1979	158.7	11.7	132.7	9.8	1067.6	78.5	-	-	1359.0
1980	179.7	9.5	228.6	12.0	1488.3	78.5	-	-	1896.6
1981	238.1	8.7	90.4	3.3	2412.6	88.0	-	-	2741.1
1982	181.8	6.3	88.3	3.1	2595.2	90.1	16.5[d]	.5	2865.3
1983	108.4	3.5	116.5	3.7	2901.2	92.3	15.6[e]	.5	3141.7
1984	153.9	6.7	64.8	2.8	2082.2	90.5	-	-	2300.9
1985	298.9	13.0	135.1	5.9	1864.1	81.1	-	-	2298.1

Table 5.1. (cont'd)

Year	Gear type								Total
	Longline		Trawl		Trap		Other[b]		
	Wt	%[c]	Wt	%	Wt	%	Wt	%	
1986	159.3	6.2	184.8	7.2	2215.9	86.6	-	-	2560.0
1987	164.4	6.2	167.9	6.4	2302.5	87.4	.3	-	2635.1
1988	243.4	10.0	176.7	7.2	2016.7	82.7	2.1	.1	2438.9
1989[f]	298.7	12.6	257.7	10.9	1815.7	76.5	-	-	2372.1

[a] Fisheries Research Board of Canada. Catch and Effort statistics of the Canadian Groundfish Fishery of the Pacific coast, 1973-1981. Statistics from 1982 to 1987 from Department of Fisheries and Oceans, Pacific Biological Station groundfish data base. Statistics for 1988 and 1989 from DFO Statistics Vancouver.

[b] Includes troll and handline.

[c] Percent of total landed by all gears within a year.

[d] Incidental to halibut longline.

[e] Includes troll, handline, sunken gillnet and catch incidental to halibut longline fishery.

[f] Preliminary to July 26, 1990

Table 5.2. Canadian sablefish landing, by gear, from west coast Vancouver Island (Major Areas 3C and 3D), 1973-1989 (round wt, metric tonnes)[a], excluding dumped and discarded fish.

	Gear type								
	Longline		Trawl		Trap		Other[b]		
Year	Wt	%[c]	Wt	%	Wt	%	Wt	%	Total
1973	3.2	0.8	50.9	12.5	353.4	86.7	Tr	Tr	407.5
1974	2.3	0.9	83.7	33.6	161.5	64.8	1.8	0.7	249.3
1975	2.3	0.9	200.3	81.8	41.5	16.9	0.9	0.4	245.0
1976	41.7	13.3	224.8	71.5	47.6	15.1	0.1	0.0	314.2
1977	27.3	3.5	688.4	87.1	68.9	8.7	5.9	0.7	790.5
1978	18.2	5.1	89.9	25.4	239.5	67.7	6.4	1.8	354.0
1979	118.3	17.5	143.4	21.2	409.8	60.5	6.0	0.9	677.5
1980	69.1	3.6	106.8	5.6	1722.5	90.6	3.0	0.2	1901.4
1981	94.8	8.6	140.2	12.8	862.4	78.6	-	-	1097.4
1982	161.9	13.2	153.2	12.5	913.3	74.2	1.9[d]	0.2	1230.3
1983	343.1	27.1	146.7	11.6	777.0	61.3	-	-	1266.8

Table 5.2. (cont'd)

	Gear type								
	Longline		Trawl		Trap		Other[b]		
Year	Wt	%[c]	Wt	%	Wt	%	Wt	%	Total
1984	211.2	13.9	120.0	7.9	1188.9	78.2	-	-	1520.1
1985	159.4	8.4	93.9	5.0	1637.2	86.6	-	-	1890.5
1986	459.2	24.8	365.4	19.7	1026.6	55.5	-	-	1851.2
1987	770.4	30.2	271.5	10.6	1512.3	59.2	-	-	2554.2
1988	1020.0	36.7	454.0	16.3	1303.1	46.9	1.2	0.1	2778.1
1989[e]	531.2	20.5	430.4	16.6	1633.8	62.9	-	-	2595.4

[a] Fisheries Research Board of Canada Catch and Effort statistics of the Canadian Groundfish Fishery of the Pacific coast, 1973-1981. Statistics from 1982 to 1987 from Department of Fisheries and Oceans, Pacific Biological Station groundfish data base. Statistics for 1988 and 1989 from DFO Statistics Vancouver

[b] Includes troll and handline.

[c] Percent of total landed by all gears within a year.

[d] Incidental to halibut longline.

[e] Preliminary to July 26, 1990

Table 5.3. Coastwide sablefish trap nominal and standardized CPUE (kg/trap), for 1978-1988.

Year	nom.	stand.
1979	16.5	14.4
1980	14.2	16.8
1981	16.6	16.0
1982	24.3	19.1
1983	16.4	14.8
1984	13.4	11.7
1985	15.7	12.7
1986	14.7	7.9
1987	13.7	11.2
1988	19.8	21.2
1989	22.6	22.6

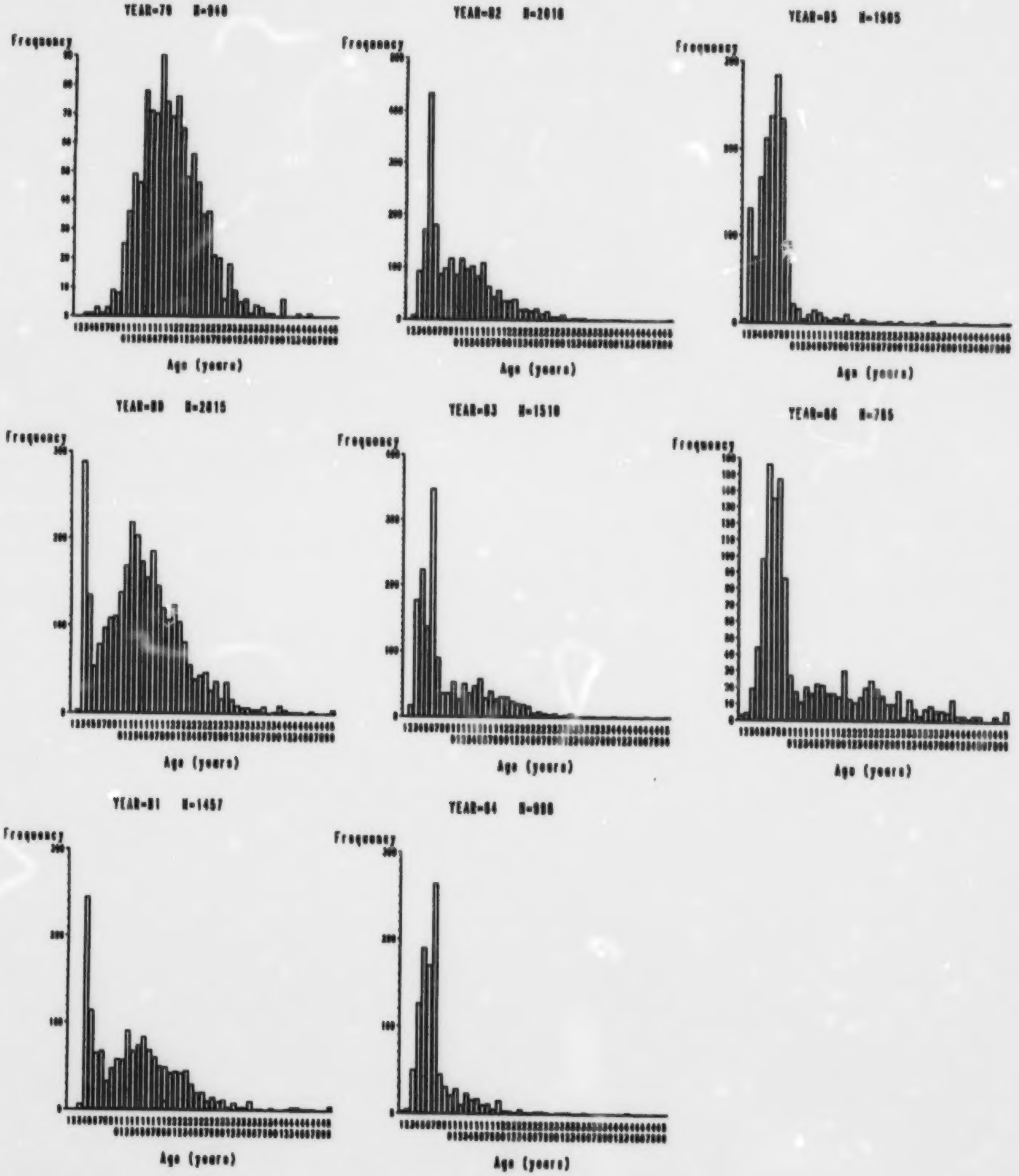


Fig. 5.1. Age frequencies of commercial catches of sablefish 1979-1989 off the west coast of Canada.

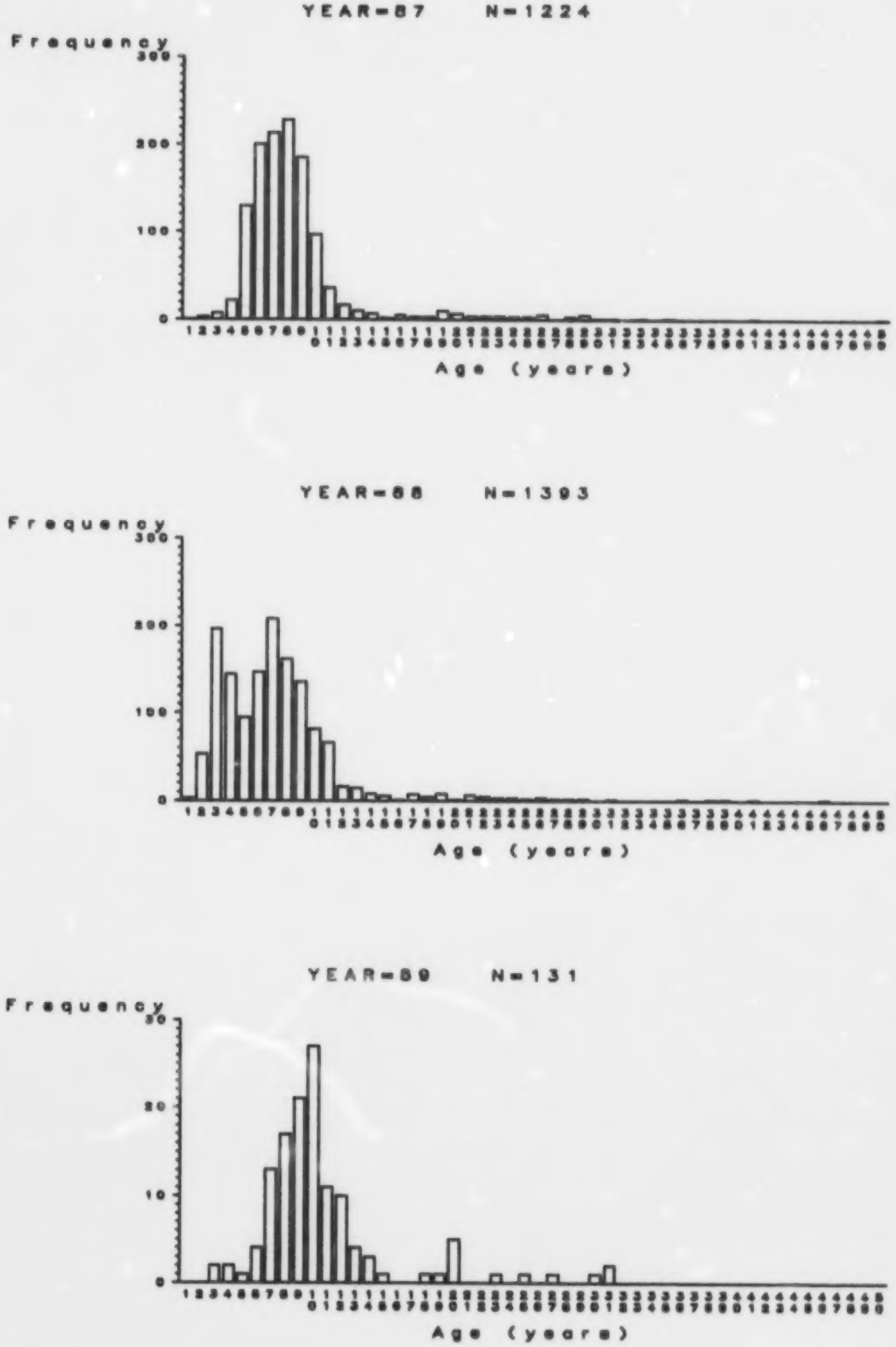

YEAR=87 N=1224
Frequency
300
200
100
0
Age (years)
YEAR=88 N=1393
Frequency
300
200
100
0
Age (years)
YEAR=89 N=131
Frequency
30
20
10
0
Age (years)

Fig. 5.1 (cont'd)

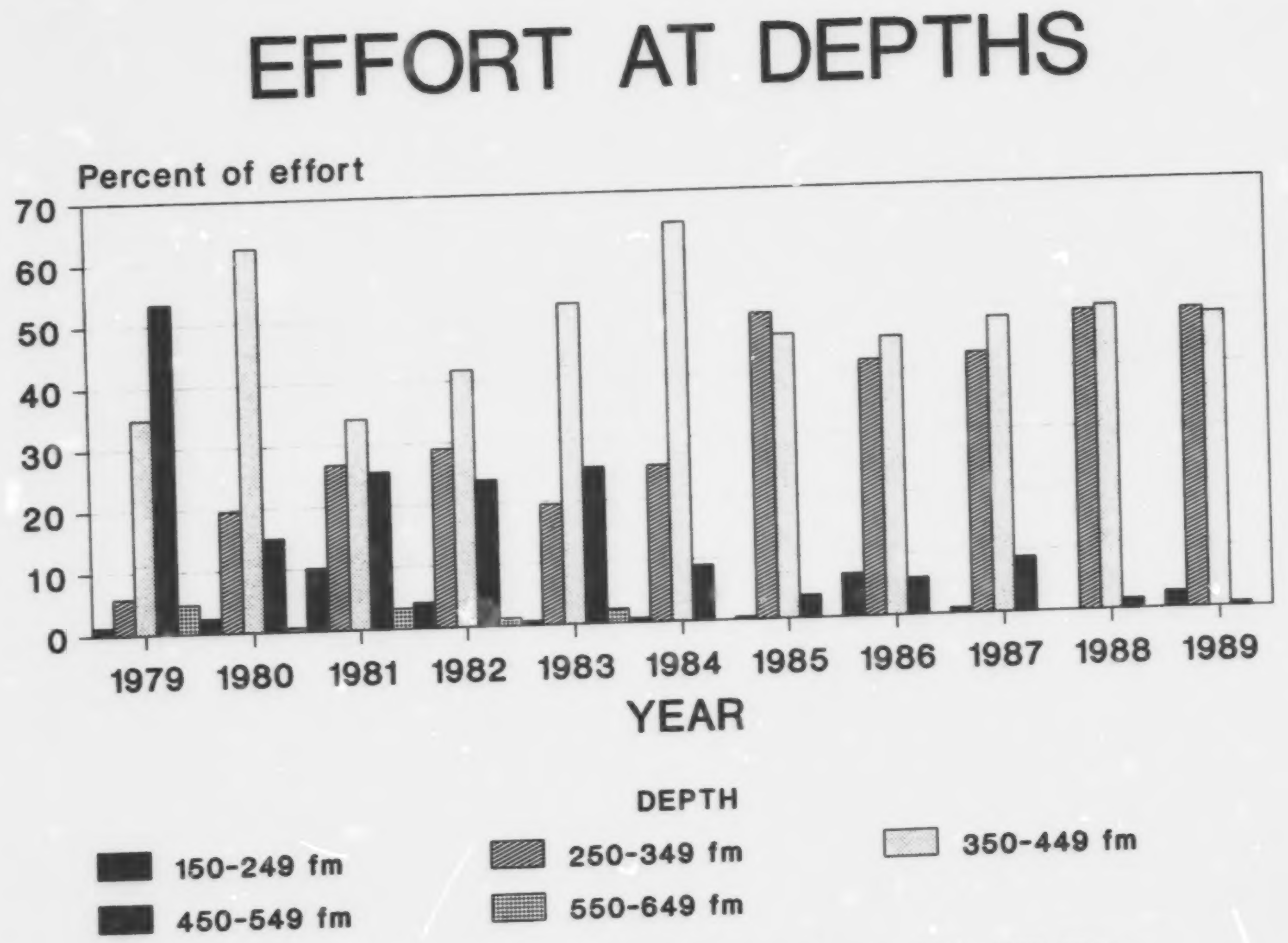
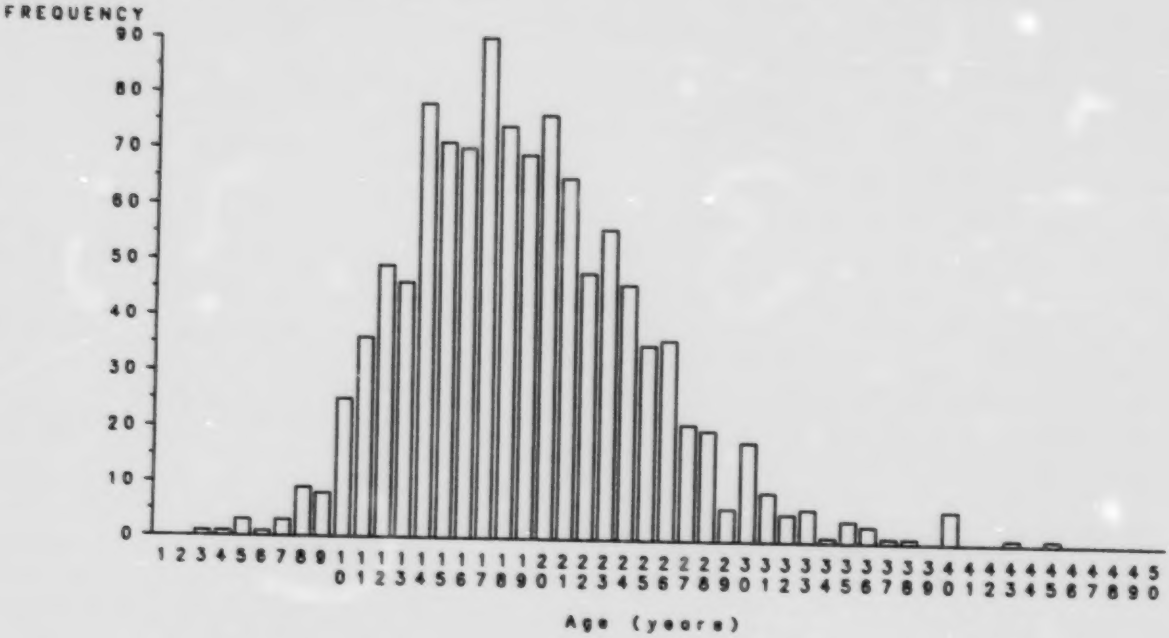


Fig. 5.2. Distribution of sablefish trap effort by average depth (fm), 1979-1989.

1979 Commercial fishery samples



1986 Research sample

AREA=Barkley Canyon DEPTH=> 400 fm

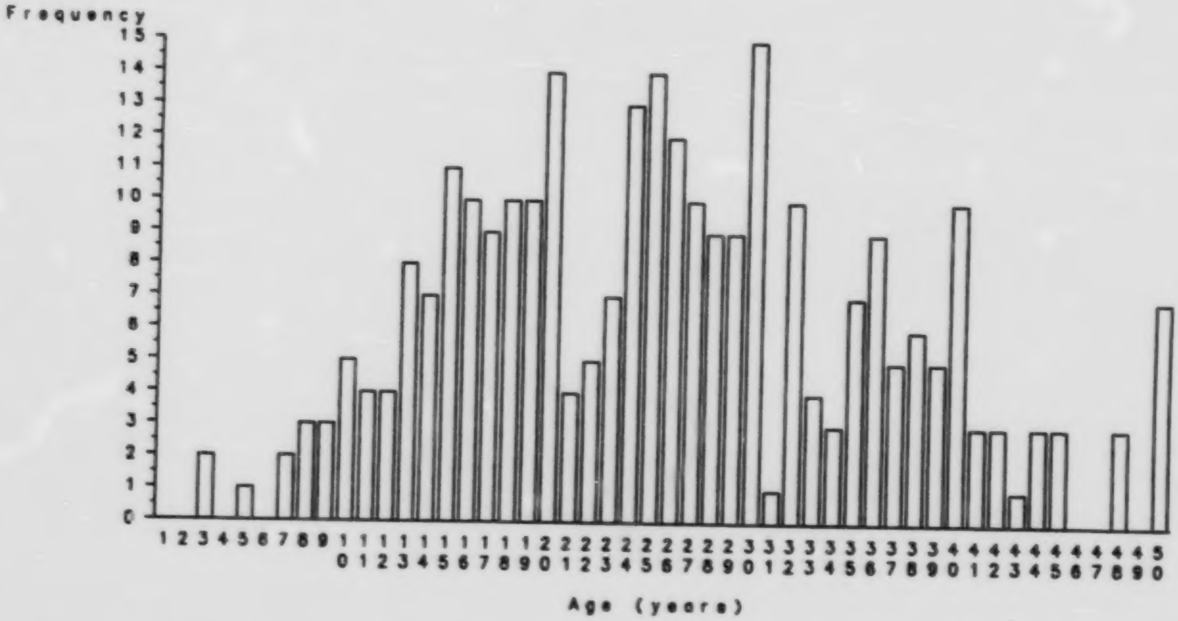


Fig. 5.3. Sablefish age frequencies for commercial catches in 1979 and from research samples in 1986 from Barkley Canyon (Deep >400 fm).

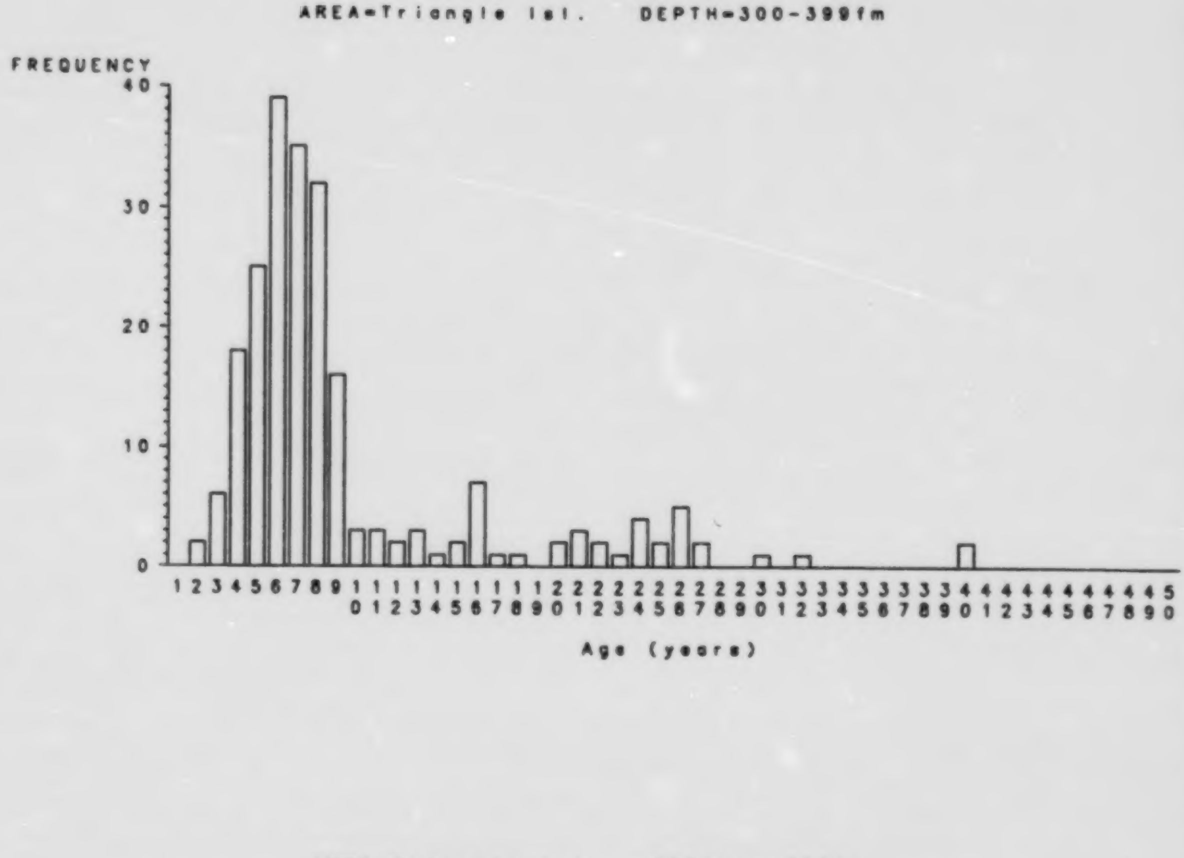


Fig. 5.4. Sablefish age frequencies from Triangle Island in 1986, by depth.

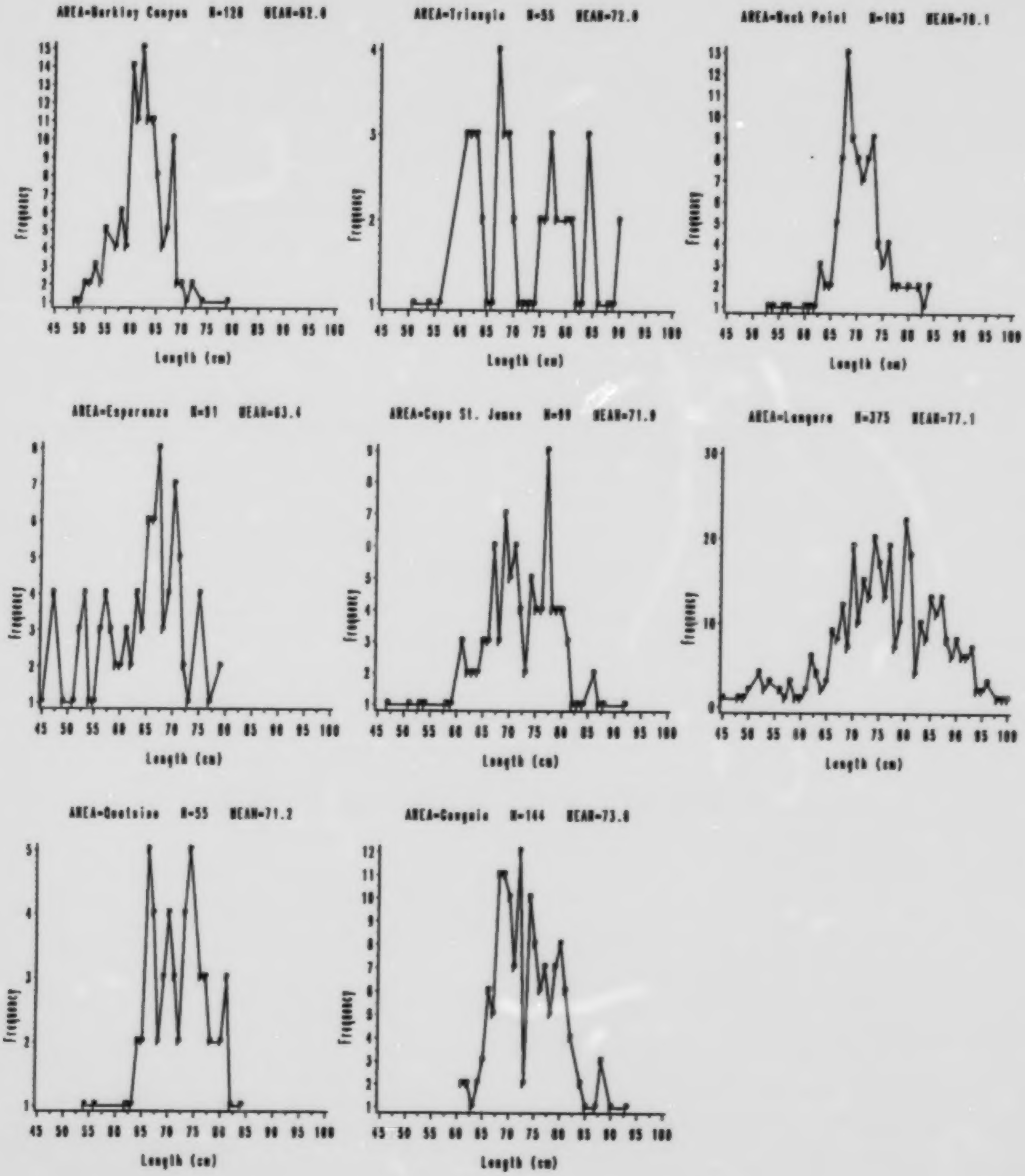


Fig. 5.5a. Research length (fork) frequencies of female sablefish by area, during November 1989 for shallow depths (<300 fm).

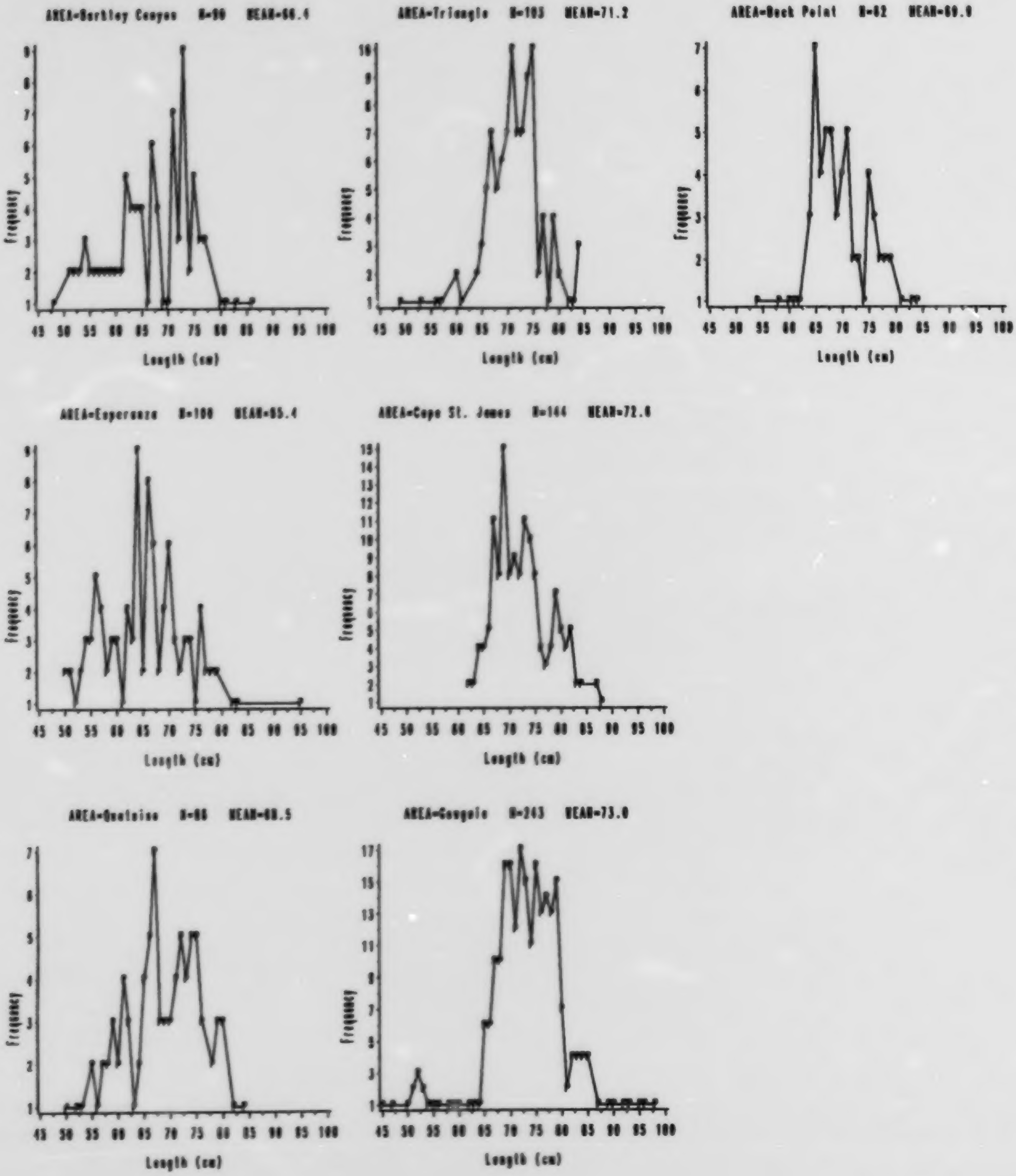


Fig. 5.5b. Research length (fork) frequencies of female sablefish by area, during November 1989 for deep depths (> 400 fm).

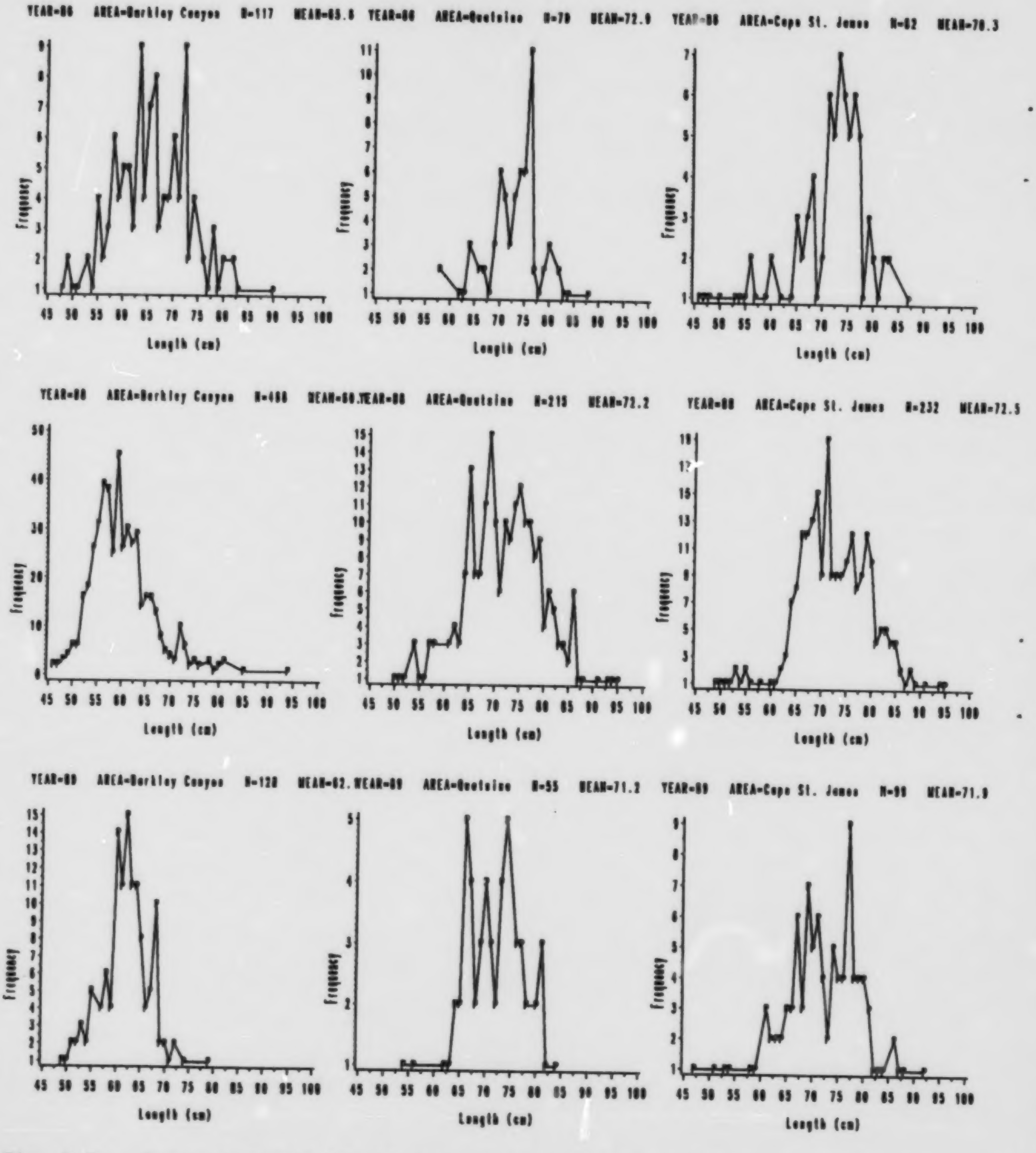


Fig. 5.6a. Research length (fork) frequencies of female sablefish by area and year, for shallow depths (<300 fm).

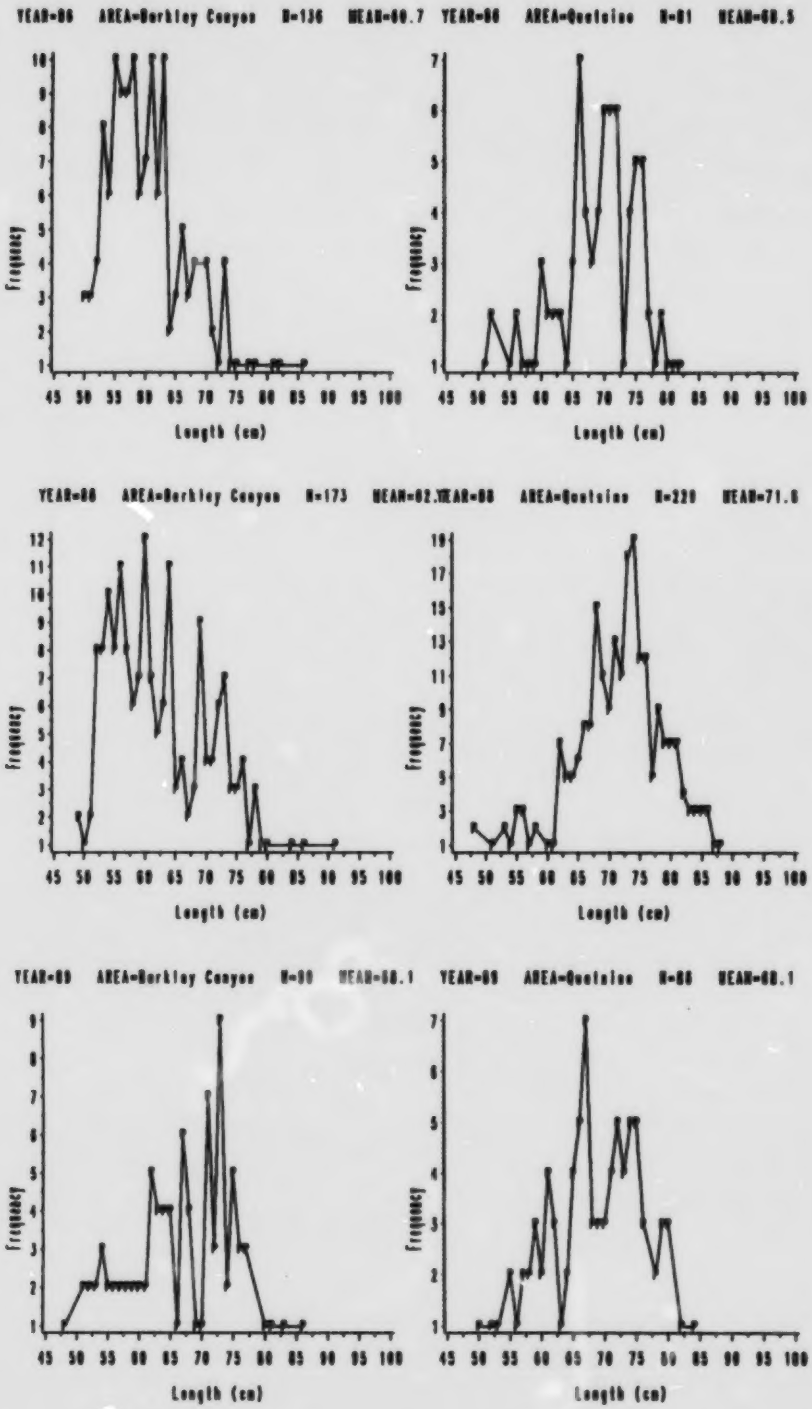


Fig. 5.6b. Research length (fork) frequencies of female sablefish by area and year, for deep depths (>400 fm).

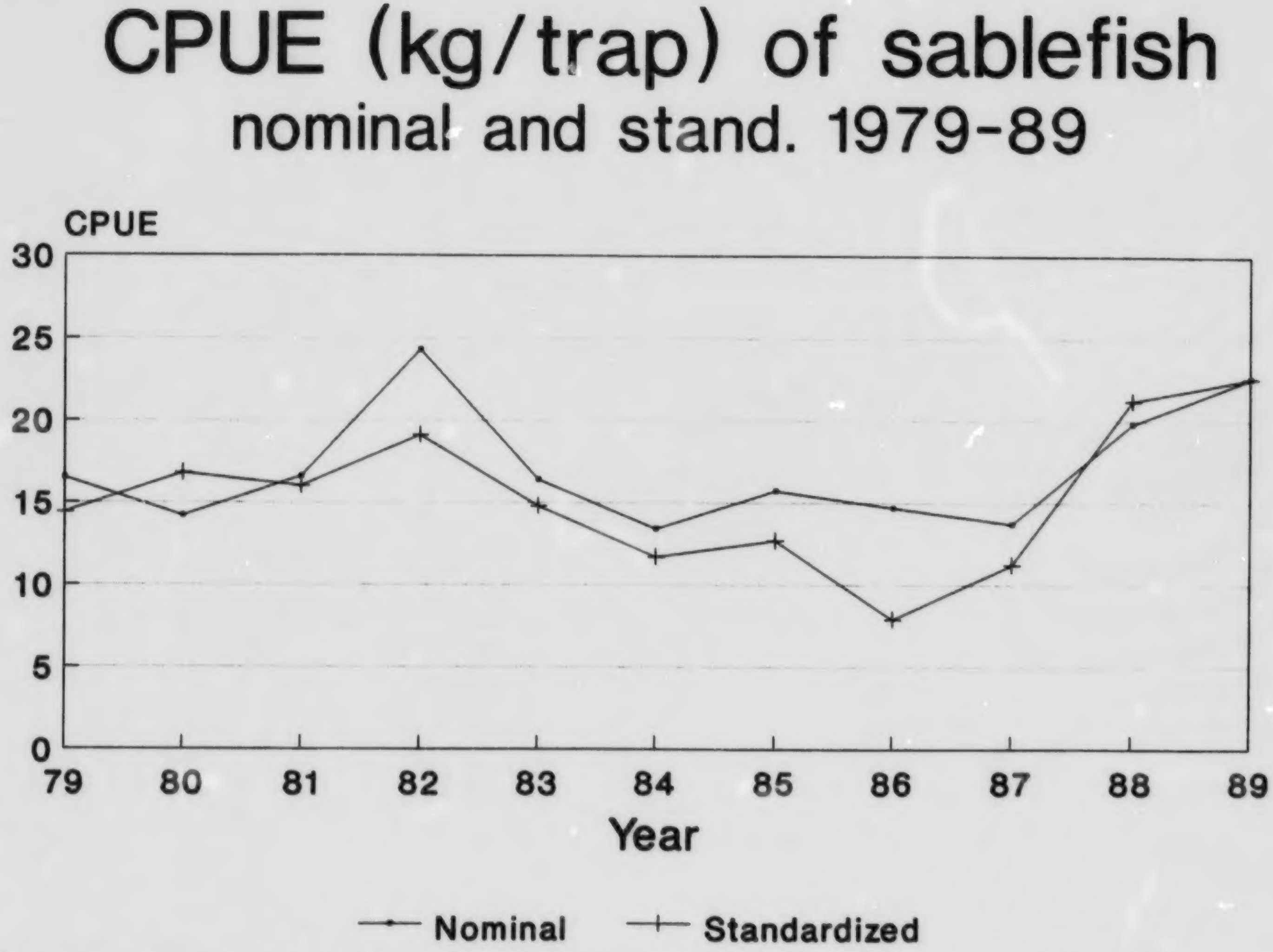


Fig. 5.7. Nominal and standardized CPUE (kg/trap) values of sablefish from 1979 to 1989.

6.0 PACIFIC HAKE

6.1. Coastwide

Yield options are not proposed on a coastwide basis.

6.2. Strait of Georgia

by M.W. Saunders

6.2.1. Introduction

Pacific hake (Merluccius productus) are the most abundant resident fish in the Strait of Georgia. Exploitation of the resident stocks has been increasing since the inception of the fishery in 1978. The proximity of the stocks to land-based processing, absence of the parasite Kudoa paniformes, which is responsible for the rapid degradation of the flesh found in offshore Pacific hake, and the potential for harvesting roe from the large spawning concentration has made this an increasingly important fishery.

6.2.2 Landing Statistics

During 1989, a total of 7079 t was landed from the Strait of Georgia, an increase of 20.1% over 1988 landings (Table 6.1). The increase is largely due to landings to a single large U.S. shore-based processor. In 1988 and 1989, the effort was spread out over several quarters, a change from the predominantly second quarter landings of previous years (Table 6.1). Prior to 1986, most of the catch came from Minor Area 17. In 1986, exploitation shifted from Minor Area 17 to Minor Area 29, a trend which continued through to 1988 with 77.3% of the catch taken from Minor Area 29 (Table 6.1 Figure 1.1). In 1989 effort again increased in Minor Area 17.

If landings in the third and fourth quarter are low, as in previous years, the total landed in 1990 will be below the 1989 catch level. The catch landed to date in 1990 is 5487 t (Table 6.2).

6.2.3. General Biological Information

6.2.4. Condition of the Stock

CPUE remained steady in 1989 at 10.091 t/hr compared to 10.190 t/hr in 1988 (Table 6.2). The preliminary CPUE value for 1990 of 6.538 t/hr represents a considerable departure from the recent rising trend in CPUE (Table 6.2). Given the schooling behaviour of this species there is some concern that CPUE in t/hr may not be a good measure of abundance.

Hydroacoustic and swept-volume surveys first conducted in 1981 were repeated in 1988. The area surveyed in both years was from the Winchelsea Islands to Sand Heads. Although the survey area covers the majority of the spawning hake stock, small concentrations are found north and south of the area. Hence the biomass estimates are not an estimate for the entire Strait of Georgia. Timing of the surveys was comparable, with all surveys taking place from mid-March to early April.

It was estimated from the 1988 hydroacoustic survey that biomass decreased to 73,300 t (95% C.L. 2,474 t) from 77,790 t (confidence limits unavailable) in 1981. Similarly the swept-volume surveys indicated a decrease to 112,545 t (95% C.L 45,326 t) in 1988 from 125,600 (95% C.L. 36,200) in 1981. Given the overlap in confidence limits it is reasonable to suggest that the stock is presently at a level of abundance which is comparable to, or slightly below the 1981 level.

Differences between hydroacoustic and swept-volume estimates are probably the result of target strength values used in the hydroacoustic calculations. The target strength value of -32 dB/m^2 that we used is considered conservative. A value of -35 dB/m^2 used in U.S. agency surveys would produce estimates roughly two times greater (Shaw et al. 1989).

Catch-at-age analysis has not changed from the assessment of Saunders and Shaw (1989). A general forward simulation model (Tyler 1982) adapted for Pacific hake, was used to project spawner biomass and yield into the future at varying levels of recruitment. The model is driven by numbers-at-age from virtual population analysis (VPA), numbers at age 2 recruiting over time and catches from 1979 to 1987. The forward simulation was used to determine appropriate levels of yield listed below.

6.2.5. Yield Options

The risk associated with the harvest levels results from the inability to predict the strength of incoming year-classes. The three levels of harvest presented are capable of sustaining the spawning stock biomass assuming low, average and high recruitment respectively. Higher risk implies a greater likelihood of depleting the stock in the event of poor recruitment.

Constant Yield

- Low risk sustainable	- 8000 t
- Sustainable	- 11000 t
- High risk sustainable	- 14000 t

6.3 West Coast Vancouver Island

by M.W. Saunders, L.J. Richards and A.V. Tyler

6.3.1 Introduction

Offshore Pacific hake are migratory fish that range from southern California to Queen Charlotte Sound. Hake are present in the Canadian zone from late spring until late fall when they migrate south to spawn off the California coast. The portion of stock in Canadian waters is composed predominantly of larger, older females.

Since 1968, more Pacific hake have been landed than any other species in the groundfish fishery on Canada's west coast. Prior to 1977, the USSR caught the major percentage of hake in the Canadian zone, with Poland and Japan accounting for much smaller quantities. Since 1977, and the declaration of the 200 mile extended fishing zone, the fishery has been divided into domestic, joint venture, and foreign operations. In 1990, the foreign fishery has been phased out, increasing the value of the fishery to Canadians.

The stock assessment produced by Dorn et al. (1990) forms the basis for much of this assessment. The assessments have been developed jointly by Canadian and U.S. scientists through a Pacific hake working group of the Technical Sub-committee (TSC) of the Canada/U.S. Groundfish Committee, which was established in the early 1980's.

6.3.2 Catch statistics

Coastwide catches of Pacific hake have increased from 251,189 t in 1988 to 308,841 t in 1989 (Table 6.3). The all-nation-catch in the Canadian zone was 97,845 t in 1989, up from 90,491 t in 1988. As in the past, most of the catch was sold directly to foreign processing vessels.

6.3.3 General biological information

The Canadian fishery continues to be supported by a series of strong year classes (Fig. 6.1, Table 6.4). In particular, the 1977 and 1980 year-classes continue to contribute significantly representing 7.1% and 57.6% by number, respectively, of the 1989 catch (Table 6.4). The strong 1984 year-class, present in the U.S. fishery for the previous three years, and present in 1988 in the Canadian fishery, is becoming an increasingly important component of the fishery. In 1988, the 1984 year-class represented 15.5% of the Canadian catch by number, a percentage which increased to 29.6% in 1989 (Table 6.4).

The U.S. fishery in 1989 was supported by the 1980 and 1984 year-classes (Table 6.4, Fig. 6.1).

In a fishery dominated by a small number of year-classes it is desirable to have the ability to forecast the relative strength of recruitment based on pre-recruit abundance. In previous assessments, measures of CPUE and percent occurrence of 0-age hake in mid-water trawl surveys conducted by the California Department of Fish and Game off the California coast over the last 20 years, were used. Unfortunately, these indices are no longer available. Fishery data (Table 6.4) and results of the 1989 triennial surveys indicate that year-class strengths have been average to poor since the strong 1984 year-class.

6.3.4 Condition of the stock

The results of the 1989 U.S. triennial acoustic and bottom trawl surveys are reported in Dorn et al. (1990). Estimates of biomass by INPFC area for the bottom trawl and acoustic surveys are presented in Tables 6.5 and 6.6, respectively. Coastwide, the biomass of hake decreased from 2142.324 thousand t in 1986 to 1636.780 thousand t in 1989 (Table 6.7). In the Canadian zone, the bottom component increased from 15.414 thousand t in 1986, to 22.756 thousand t in 1989 (Table 6.7). The acoustic component however, decreased from 284.316 thousand t in 1986 to 104.603 thousand t in 1989 (Table 6.7). A number of problems with the 1989 U.S. survey in the Canadian zone are currently under review. We do not believe the decrease in abundance to be as severe as reported.

The approach taken in this assessment is similar to that of the previous one (Saunders et al. 1990, Dorn and Methot 1990). We used catch-at-age analysis tuned to independent U.S. triennial survey estimates to assess the current status of the stock, and an age-structured forward simulation model to examine long and short-term yield options. However, the catch-at-age analysis used in this assessment has been modified to model the two fisheries independently.

Catch-at-age estimates for the U.S. fishery from 1978-89 were calculated using the method of Kimura (1987). Catch-at-age in the Canadian zone was calculated by using the ratio of the numbers-at-age to the weights-at-age in the age sample times the total catch. The weights-at-age in the sample were the sum of the weights from individual fish as derived from length-weight relationships for males and females sampled in the given year. Canadian and U.S. catch-at-age were summed to provide coastwide estimates (Table 6.4). U.S. and Canadian mean lengths at age and length-weight growth coefficients are presented in Table 6.8.

As in the previous assessment, a form of the stock synthesis model developed by Methot (1986 and 1989) was used to determine the population numbers at age. Refer to Dorn et al. (1990) for specific details of the current analysis.

Briefly, the synthesis model is a separable catch-at-age analysis that is tuned to the survey biomass and survey estimates of age composition. In the past, catch-at-age was modelled as a single fishery with the Can. and U.S. catch-at-age matrices combined. This year, Can. and U.S. fishery estimates and the U.S. survey estimates for the Canadian and U.S. zone were modeled separately. At the end of each year, fish from both zones were assumed to mix and spawn. The stock was split between the U.S. and Canada using a migration curve (Fig. 6.2) based on an analysis of U.S. survey data (Dorn et al. 1990; Dorn and Methot 1990).

The U.S. survey data was adjusted to account for the proportion of the stock north of the survey areas. The expansion factors were determined by summing the available habitat along the 200m isobath, north of the surveys and dividing it by the hake habitat within the survey area. The estimated biomass north of the survey was 14% of the surveyed biomass in Canada in 1977, 1980, and 1989; 20% in 1983; and 23% in 1986. A hydroacoustic survey was conducted in August 1990 throughout the range of hake in the Canadian zone. This survey should provide more accurate estimates of hake in the northern portion of the zone for future assessments.

The model simulates the population's history and compares the model estimates with observations of the catch. The model uses as input, catch, biomass and age composition from the two fisheries, survey biomass (Can. and U.S), and survey age composition (Can. and U.S). The goodness of fit to these observations is evaluated in terms of log likelihood. The model can estimate population age composition in each year, recruitment in each subsequent year, fishery age-specific selectivity factors, and age-specific selectivity by the survey. Year-specific fishing mortalities are not estimated as parameters but rather tuned to the level necessary to match the observed catch and biomass. Stock synthesis estimates are presented in Table 6.9 and Table 6.10.

As in the previous assessment, an age-structured simulation model, utilizing information on mortality, growth, abundance (from the stock synthesis model) and recruitment (from the stock synthesis model), was used to produce long-term estimates of hake production and projected yields for 1990. The age-structured model is a modification of Walters' (1969) generalized model for fish populations as developed by Francis (1985). An instantaneous rate of natural mortality (M) of 0.273 was used for all ages in both analyses. This M value is higher than the 0.2 value used in the previous assessment and was estimated using a cohort decay method outlined in Dorn et al. (1990).

Estimating recruitment continues to be problematic with the absence of a stock-recruit relationship. As in the previous assessment recruitment estimates were obtained by sampling, with replacement, the actual recruitment time series (1958-87).

The model was run in two modes, equilibrium and look-ahead. The equilibrium model utilizes a theoretical fished population and is run over 1000 years to establish optimal levels of effort, where yield is maximized and the integrity of the stock preserved. Over the observed time series there is no evidence to suggest that a relationship between stock size and recruitment exists. Hence, it is difficult to determine a level fishing that may result in stock collapse. In this assessment the approach taken was to explore impact of varying fishing strategies on the level of female spawner biomass relative to the long-term levels of female spawner biomass for an unfished population. The 0.1 percentile of the female spawning biomass (457,000 t) (Fig. 6.3) was chosen as cautionary level of female spawning biomass. Risk was assessed for each harvest strategy by determining the probability that female spawning biomass drops below this level. Low risk strategies are those where the probability of dropping below the cautionary level of spawning biomass is low and the reverse is true for high risk strategies.

Dorn et al. (1990) point out that while the numbers are arbitrary, they result in fishing mortality rates that correspond to other reference points commonly used to guide management decisions. Low risk options approach an F=M strategy, moderate risk level are similar to those that would be calculated from surplus production estimates of MSY and the high risk level is similar to an $F_{0.1}$ level.

A summary of parameter values used in the 1000-year runs is presented in Table 6.11. Runs were conducted under three possible management scenarios, constant effort and variable effort. The variable effort strategy is similar to that described by Shuter and Koonce (1985) as one which greatly reduces the risk of stock collapse when compared with constant catch or constant effort. Fishing mortality in a given year was calculated as follows:

F_i = fishing mortality in year i
$= F_{opt} (SB_i / SB_{opt})$

Where,

F_{opt} = optimal fishing mortality
SB_{opt} = spawner biomass level at F_{opt}
SB_i = spawner biomass in year i

A hybrid strategy that combines features of the constant and variable F policies was implemented to reduce the extreme variation in yields associated with the variable F policy options selected in recent years by managers. The hybrid strategy uses a constant F when female spawning biomass is above the mean level, and variable F when it is below the mean. A summary of equilibrium run results is presented in Table 6.12

The optimal levels of effort and biomass were then used in look-ahead simulations to make projections of future yields. The starting population in 1989 is the numbers-at-age from the stock synthesis analysis. Recruitment of the 1989, 1990 and 1991 year-classes provide some uncertainty in the yield projections. Four alternative are considered. The starting parameters for the look ahead runs are presented in Table 6.13. A time trend of female spawning biomass from 1958 to the present with projections under a moderate risk hybrid harvesting strategy and the four different recruitment scenarios is presented in Fig. 6.4.

The results of 1991-93 catch projections under the various recruitment alternatives are presented in Table 6.14. The yield levels for 1990 range from 146 to 327 thousand t. The largest portion of the range is associated with the risk level, while the recruitment and effort strategy affect yield to a lesser degree.

Managers should note that, if recruitment continues to be weak, the projected yields will decrease over the next several years. The decrease in yield for 1991 is not as drastic as predicted in last years' assessments (Saunders et al. 1990, Dorn and Methot 1990) because of inclusion of 1989 hydroacoustic and trawl survey data. Stock synthesis runs using these data indicate that the 1980 and 1984 year-classes are stronger than previously believed.

6.3.5 Yield options

The yield options for the coastwide fishery for hybrid and constant effort strategies are presented below. We have used only yields from the pessimistic recruitment scenario (D), given there is no evidence for strong recruitment since 1984. Variable yield options have not been presented, given managements' preference for a more stable yield.

No recommendation regarding allocation of the coastwide yield between the two countries is presented. Since U.S and Canadian managers are presently involved in discussions of this issue.

Hybrid policy:

Low risk sustainable - 175 thousand t
Sustainable - 253 thousand t
High risk sustainable - 311 thousand t

Constant effort:

Low risk sustainable - 146 thousand t
Sustainable - 200 thousand t
High risk sustainable - 252 thousand t

Table 6.1. Pacific hake landings (t), excluding dumped and discarded fish for the second quarter and whole year for Minor Areas 14, 17 and 29, and Major Area 4B (Strait of Georgia) during 1977-1989.

	1977		1978		1979		1980		1981		1982		1983	
Region	Q2	Yr	Q2	Yr	Q2	Yr	Q2	Yr	Q2	Yr	Q2	Yr	Q2	Yr
Minor Area														
14	0	0	-	-	-	-	0	385	448	523	-	-	53	53
17	-	-	0	1	484	484	-	-	76	182	1927	2420	2208	2240
29	-	-	0	2	2	2	0	5	810	1434	0	12	0	11
Major Area														
4B	0	0	1	2	486	516	1	508	1364	2409	1927	2824	3078	3122

	1984		1985		1986		1987		1988		1989	
Region	Q2	Yr	Q2	Yr	Q2	Yr	Q2	Yr	Q2	Yr	Q2	Yr
Minor Area												
14	368	368	15	77	849	1209	686	796	0	3	530	1238
17	805	1736	1700	3718	1073	1158	1216	1444	68	944	2113	3471
29	544	951	67	982	618	2296	3832	5852	1575	4559	704	1538
Major Area												
4B	1717	3056	1827	4976	2540	5031	5811	9127	1643	5895	3471	7079

Table 6.2. Pacific hake landings, CPUE and effort from the Strait of Georgia (Major Area 4B), 1977-1990.

Year	Total catch (t)	CPUE[a] (t/hr)	Effort[b] (hr)
1977	.04	0	0
1978	2	0	0
1979	516	10.207	51
1980	508	4.583	111
1981	2409	8.937	270
1982	2824	4.796	589
1983	3121	4.465	699
1984	4599	6.780	678
1985	4976	4.448	1119
1986	5031	7.450	675
1987	9127	8.019	1138
1988	5895	10.190	579
1989	7079	10.091	702
1990[c]	5487	6.538	839

[a] CPUE @ 25% qualification level.

[b] Effort = Total catch/CPUE.

[c] Preliminary to August 31, 1990.

Table 6.3.--Annual catches of Pacific hake (1,000 t) in U.S. and Canadian management zones by foreign, joint venture (JV), and domestic fleets, 1966-89 (from Dorn et al. 1990).

	U. S.				Canada				
Year	Foreign	JV	Domestic	Total	Foreign	JV	Domestic	Total	Combined total
1966	137.000	0.000	0.000	137.000	0.700	0.000	0.000	0.700	137.700
1967	168.699	0.000	8.963	177.658	36.713	0.000	0.000	36.713	214.371
1968	60.660	0.000	0.159	60.819	61.361	0.000	0.000	61.361	122.180
1969	86.187	0.000	0.093	86.280	93.851	0.000	0.000	93.851	180.131
1970	159.509	0.000	0.066	159.575	75.009	0.000	0.000	75.009	234.584
1971	126.485	0.000	1.428	127.913	26.699	0.000	0.000	26.699	154.612
1972	74.093	0.000	0.040	74.133	43.413	0.000	0.000	43.413	117.546
1973	147.441	0.000	0.072	147.313	15.125	0.000	0.001	15.126	162.439
1974	194.108	0.000	0.001	194.109	17.146	0.000	0.004	17.150	211.259
1975	205.654	0.000	0.002	205.656	15.704	0.000	0.000	15.704	221.360
1976	231.331	0.000	0.218	231.549	5.972	0.000	0.000	5.972	237.521
1977	127.013	0.000	0.489	127.502	5.191	0.000	0.000	3.453	130.955
1978	96.827	0.856	0.689	98.372	3.453	1.814	0.000	6.464	104.836
1979	114.909	8.834	0.937	124.680	7.900	4.233	0.302	12.435	137.115
1980	44.023	27.537	0.792	72.352	5.273	12.214	0.097	17.584	89.936
1981	70.365	43.556	0.839	114.760	3.919	17.159	3.283	24.361	139.121
1982	7.089	67.464	1.024	75.577	12.479	19.676	0.002	32.155	107.732
1983	0.000	72.100	1.050	73.150	13.117	27.657	0.000	40.774	113.924
1984	14.722	78.889	2.721	96.382	13.203	28.906	0.000	42.109	138.491
1985	49.853	31.692	3.894	85.439	10.533	13.237	1.192	24.962	110.401
1986	69.861	81.640	3.463	154.964	23.743	30.136	1.774	55.653	210.617
1987	49.656	105.997	4.795	160.448	21.453	48.076	4.170	73.699	234.147
1988	18.041	135.781	6.876	160.698	39.714	50.182	0.594	90.491	251.189
1989	0.000	203.578	7.418	210.996	31.589	66.256	0.000	97.845	308.841
Mean 1966-89				131.555				38.070	169.625

Sources: 1966-80 from Bailey et al. 1980; 1981-89 from Pacific Fishery Information Network (PacFIN), Pacific Fishery Management Council, Metro Center, Suite 170, 2000 SW. First Avenue, Portland, OR 97201; Canadian catches reported by Mark Saunders, Pacific Biological Station, Department of Fisheries and Oceans, Nanaimo, B.C. V9R 5K6, Pers. commun., January 1990.

Table 6.4.--Catch at age (millions of fish) for the Pacific hake fisheries, 1978-89. Separate tables are given for the U.S. fisheries, the Canadian fisheries and the combined fisheries. These numbers include the foreign, joint venture and domestic fisheries (from Dorn et al. 1990).

								Age								
Year	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	Total
								U.S. fisheries								
1978	0.01	0.02	4.56	8.58	51.87	9.48	20.32	38.57	5.74	2.48	1.28	0.52	0.20	0.05	0.01	143.69
1979	0.00	4.34	8.74	17.41	10.15	48.01	15.47	29.48	20.82	4.25	1.70	0.50	0.22	0.05	0.03	161.16
1980	0.00	0.13	24.67	2.16	6.90	7.16	20.11	9.57	11.99	9.92	1.74	1.35	1.01	0.59	0.14	97.42
1981	13.38	1.25	2.30	97.62	6.89	9.64	6.77	23.33	6.26	7.24	7.05	0.95	0.48	0.12	0.13	183.43
1982	0.00	27.51	1.93	1.57	57.88	5.02	5.[illegible]	5.02	11.96	2.43	2.53	4.64	0.34	0.13	0.03	126.77
1983	0.00	0.00	86.60	7.22	3.63	36.79	4.68	3.72	3.32	5.24	1.62	1.00	1.00	0.16	0.14	155.12
1984	0.00	0.00	2.59	164.97	7.18	5.18	17.54	2.17	1.24	0.82	1.34	0.21	0.20	0.31	0.03	203.78
1985	2.27	0.55	1.32	12.36	113.50	9.74	4.30	6.75	0.61	0.34	0.24	0.36	0.00	0.00	0.00	152.34
1986	0.00	62.92	12.88	1.85	9.34	171.79	21.55	10.76	12.45	1.53	1.05	0.38	0.79	0.15	0.05	307.49
1987	0.00	0.00	124.20	6.58	1.68	2.72	151.56	7.89	3.09	14.87	0.57	0.15	0.15	1.25	0.00	314.71
1988	0.00	1.22	1.31	172.76	8.02	1.40	2.60	96.93	5.16	0.72	8.32	0.15	0.24	0.00	0.65	299.49
1989	0.00	8.65	9.57	3.88	257.20	7.80	2.46	2.74	106.63	6.62	0.87	5.37	0.03	0.12	0.57	412.51
								Canadian fisheries								
1978	0.00	0.00	0.00	0.20	0.35	0.28	1.06	1.31	1.12	0.62	0.48	0.21	0.18	0.09	0.00	5.90
1979	0.00	0.00	0.00	0.21	0.62	1.30	1.14	2.10	3.02	1.10	0.79	0.37	0.25	0.17	0.12	11.18
1980	0.00	0.00	0.00	0.00	0.47	0.62	2.46	0.92	1.18	6.74	1.27	0.62	0.62	0.20	0.00	15.07
1981	0.00	0.00	0.00	1.01	0.27	1.41	1.38	4.28	0.85	2.36	6.18	1.49	0.60	0.85	0.00	20.66
1982	0.00	0.00	0.00	0.69	13.35	1.10	1.44	1.41	4.41	1.00	0.78	6.04	0.59	0.47	0.00	31.27
1983	0.00	0.06	14.02	1.03	1.80	32.15	1.29	1.87	1.67	5.59	0.77	0.26	3.41	0.26	0.13	64.30
1984	0.00	0.00	1.11	13.27	1.73	9.26	20.86	2.04	2.35	1.54	4.81	0.93	0.80	2.65	0.37	61.71
1985	0.00	0.06	0.06	2.45	8.03	1.65	3.25	9.62	0.49	0.55	0.55	1.65	0.37	0.00	1.59	30.33
1986	0.00	0.14	0.14	0.28	3.97	38.41	2.41	2.41	11.48	1.28	0.57	0.99	1.42	0.43	1.42	65.33
1987	0.00	0.00	0.90	0.60	0.15	2.56	70.71	2.86	2.86	10.38	0.60	0.45	1.20	0.90	1.20	95.38
1988	0.00	0.00	0.31	15.28	0.62	1.13	2.36	66.66	2.26	1.44	7.90	0.51	0.21	0.21	0.62	99.48
1989	0.00	0.00	0.20	0.59	35.55	0.20	0.39	0.59	69.34	1.76	1.37	8.59	0.39	0.20	1.17	120.32
								Combined fisheries								
1978	0.01	0.02	4.56	8.78	52.21	9.76	21.38	39.88	6.86	3.10	1.76	0.73	0.38	0.14	0.01	149.58
1979	0.00	4.34	8.74	17.62	10.76	49.31	16.61	31.58	23.83	5.34	2.49	0.87	0.46	0.22	0.15	172.34
1980	0.00	0.13	24.67	2.16	7.36	7.77	22.57	10.49	13.16	16.65	3.00	1.97	1.62	0.78	0.14	112.49
1981	13.38	1.25	2.30	98.63	7.16	11.05	8.16	27.60	7.11	9.60	13.23	2.44	1.08	0.97	0.13	204.09
1982	0.00	27.51	1.93	2.25	71.24	6.11	7.22	6.43	16.37	3.43	3.31	10.67	0.94	0.60	0.03	158.04
1983	0.00	0.06	100.61	8.25	5.43	68.93	5.96	5.59	4.99	10.83	2.39	1.26	4.41	0.42	0.27	219.42
1984	0.00	0.00	3.71	178.24	8.91	14.43	38.39	4.20	3.58	2.36	6.15	1.14	1.00	2.97	0.40	265.49
1985	2.27	0.61	1.38	14.81	121.52	11.39	7.55	16.37	1.10	0.89	0.79	2.02	0.37	0.00	1.59	182.67
1986	0.00	63.06	13.02	2.13	13.31	210.20	23.96	13.17	23.93	2.80	1.62	1.37	2.20	0.58	1.46	372.82
1987	0.00	0.00	125.10	7.18	1.83	5.28	222.27	10.74	5.95	25.25	1.17	0.60	1.35	2.15	1.20	410.09
1988	0.00	1.22	1.62	188.05	8.64	2.53	4.96	163.59	7.42	2.15	16.22	0.67	0.44	0.21	1.26	398.96
1989	0.00	8.65	9.76	4.46	292.75	8.00	2.85	3.32	175.98	8.38	2.24	13.96	0.42	0.31	1.74	532.82

Sources: Jerald Berger, U.S. Foreign Fishery Observer Program, Alaska Fisheries Science Center, National Marine Fisheries Service, NOAA, BIN C15700, 7600 Sand Point Way NE., Seattle, WA 98115, Pers. commun., May 1990. Canadian statistics reported by Mark Saunders, Pacific Biological Station, Department of Fisheries and Oceans, Nanaimo, B.C. V9R 5K6, Pers. commun., May 1990.

Table 6.5.--Estimated population biomass at age (1,000 t) by INPFC area for 1989 West coast Pacific hake bottom trawl survey (from Dorn et al. 1990).

	INPFC Areas						
Age	Conc.	Mont.	Eureka	Col.(S)	Col.(N)/US Van.	Can.	Total
0	0.052	0.038	0.000	0.000	0.000	0.000	0.090
1	0.911	3.909	2.823	4.305	0.000	0.002	11.950
2	0.125	4.112	2.335	3.489	0.042	0.009	10.111
3	0.018	1.895	1.088	1.620	0.066	0.000	4.687
4	0.008	1.743	0.794	1.628	0.970	0.000	5.143
5	0.052	15.981	11.187	34.629	32.033	1.794	95.675
6	0.006	2.459	0.608	2.107	0.692	0.323	6.194
7	0.012	4.228	0.724	2.506	1.984	0.271	9.725
8	0.004	1.171	0.304	1.006	0.551	0.125	3.160
9	0.122	33.968	15.513	55.791	59.559	12.371	177.323
10	0.012	2.839	0.442	1.637	1.239	0.636	6.805
11	0.001	0.176	0.071	0.318	0.528	0.000	1.095
12	0.066	7.908	1.935	7.664	8.975	3.169	29.718
13	0.002	0.061	0.009	0.038	0.048	0.000	0.158
14	0.005	0.160	0.012	0.078	0.087	0.000	0.342
15+	0.008	0.673	0.225	0.684	1.147	0.998	3.735
Total	1.403	81.321	38.069	117.501	107.921	19.695	365.910

Table 6.6.--Estimated population biomass at age (1,000 t) by INPFC area for 1989 West coast Pacific hake acoustic survey (from Dorn et al. 1990).

	INPFC Areas						
Age	Conc.	Mont.	Eureka	Col.(S)	Col.(N)/US Van.	Can.	Total
0	31.693	0.000	0.000	0.000	0.000	0.000	31.693
1	0.000	0.186	0.000	0.000	0.000	0.000	0.186
2	0.000	45.995	34.737	2.694	0.414	0.026	83.866
3	0.000	11.176	11.388	2.548	1.331	0.181	26.624
4	0.000	2.261	3.777	1.889	1.261	0.325	9.513
5	0.000	91.990	231.679	187.162	141.799	46.243	698.873
6	0.000	1.971	4.249	3.689	2.818	1.021	13.748
7	0.000	1.309	2.000	1.992	1.997	1.029	8.327
8	0.000	1.113	2.161	3.385	2.956	1.323	10.938
9	0.000	44.576	64.084	90.893	90.148	46.172	335.873
10	0.000	1.554	3.285	4.078	3.772	1.752	14.441
11	0.000	0.202	0.225	0.541	0.560	0.302	1.830
12	0.000	5.168	2.869	4.634	6.544	5.603	24.818
13	0.000	0.000	0.000	0.000	0.000	0.000	0.000
14	0.000	0.000	0.000	0.000	0.000	0.000	0.000
15+	0.000	1.936	0.000	0.185	0.778	0.626	3.525
Total	31.693	209.437	360.454	303.69	254.378	104.603	1264.255

Table 6.7.--Pacific hake trawl and acoustic biomass (1,000 t) by region based on bottom trawl and acoustic surveys in 1977, 1980, 1983, 1986, and 1989. The trawl survey estimates of biomass in the Canadian zone in 1977 and 1986 were interpolated as described in the text. The expansion factor used to account for the unsurveyed biomass north of survey grid has not been used to adjust these biomass estimates. BT-bottom trawl estimate, A-acoustic estimate, T-total (from Dorn et al. 1990).

					Vancouver		
		Mont.	Eureka	Columb.	U.S.	Canada	Total
1977	BT	17.707	10.153	31.548	6.523	10.376	
	A	108.087	360.944	316.44	152.439	191.382	
	T	125.794	371.097	347.988	158.962	201.758	1205.599
1980	BT	140.948	11.338	19.858	11.770	4.385	
	A	579.841	182.783	260.477	159.931	162.402	
	T	720.789	194.121	280.335	171.701	166.787	1533.733
1983	BT	19.164	43.559	56.665	8.068	1.352	
	A	56.203	252.265	397.168	236.507	258.725	
	T	75.367	295.824	453.833	244.575	260.077	1329.676
1986	BT	95.953	45.228	78.568	19.403	15.414	
	A	770.292	192.205	402.469	238.476	284.316	
	T	866.245	237.433	481.037	257.879	299.730	2142.324
1989	BT	84.834	37.694	205.729	21.501	22.765	
	A	241.13	360.454	420.665	137.405	104.603	
	T	325.964	398.148	626.394	158.906	127.368	1636.780

Table 6.8.--U.S. and Canadian mean fishery length at age (cm) and coefficients of a length-weight relationship (cm to g) for Pacific hake in 1989 (from Dorn et al. 1990).

Age	Males		Females	
	U.S.	Canada	U.S.	Canada
	Length at age			
2	32.8	---	33.1	---
3	36.9	---	38.3	48.0
4	39.8	---	41.1	46.7
5	42.9	44.4	43.6	45.2
6	43.0	---	44.5	47.0
7	45.7	54.0	44.9	54.0
8	46.6	---	45.9	48.8
9	45.6	48.8	46.8	50.9
10	45.7	50.4	47.2	52.0
11	47.5	50.5	47.9	55.0
12	50.1	52.5	51.8	56.2
13	53.0	48.5	58.7	---
14	50.3	---	57.6	59.5
15+	53.5	70.0	53.5	59.6
	Length-weight coefficients			
a	0.0361	0.0096	0.0080	0.0507
b	2.5232	2.8930	2.9168	2.4760

Sources: Jerald Berger, U.S. Foreign Fishery Observer Program, Alaska Fisheries Science Center, National Marine Fisheries Service, NOAA, BIN C15700, 7600 Sand Point Way NE., Seattle, WA 98115, Pers. commun., May 1990. Canadian statistics reported by Mark Saunders, Pacific Biological Station, Department of Fisheries and Oceans, Nanaimo, B.C. V9R 5K6, Pers. commun., May 1990.

Table 6.9.--Numbers at age (millions of fish) for the coastal population of Pacific hake as estimated by a geographic version of the stock synthesis model, 1977-89. Separate tables are given for the U.S. zone, the Canadian zone and the total population (from Dorn et al.).

	Age													
Year	2	3	4	5	6	7	8	9	10	11	12	13	14	15
							U.S. Zone							
1977	295.0	234.0	747.0	163.0	126.0	580.0	92.0	66.0	43.0	34.0	26.0	5.0	48.0	180.0
1978	180.0	229.0	176.0	516.0	100.0	74.0	356.0	60.0	44.0	29.0	24.0	19.0	3.0	173.0
1979	2,162.0	140.0	172.0	121.0	320.0	60.0	46.0	237.0	41.0	30.0	20.0	17.0	14.0	135.0
1980	285.0	1,685.0	107.0	125.0	84.0	227.0	45.0	37.0	192.0	33.0	25.0	17.0	15.0	140.0
1981	355.0	223.0	1,287.0	77.0	82.0	51.0	138.0	28.0	24.0	126.0	22.0	17.0	12.0	114.0
1982	6,258.0	271.0	156.0	756.0	36.0	35.0	22.0	65.0	14.0	11.0	63.0	11.0	9.0	74.0
1983	333.0	4,703.0	184.0	89.0	383.0	19.0	20.0	13.0	39.0	8.0	7.0	39.0	7.0	58.0
1984	76.0	258.0	3,633.0	141.0	71.0	325.0	17.0	18.0	12.0	35.0	7.0	6.0	38.0	68.0
1985	196.0	59.0	199.0	2,713.0	102.0	51.0	243.0	13.0	14.0	9.0	28.0	6.0	5.0	95.0
1986	6,110.0	152.0	44.0	135.0	1,598.0	55.0	28.0	139.0	7.0	8.0	5.0	17.0	3.0	65.0
1987	102.0	4,760.0	116.0	32.0	93.0	1,116.0	40.0	21.0	106.0	5.0	6.0	4.0	14.0	63.0
1988	252.0	79.0	3,566.0	79.0	19.0	51.0	623.0	23.0	12.0	63.0	3.0	4.0	3.0	56.0
1989	903.0	197.0	60.0	2,571.0	53.0	12.0	33.0	417.0	15.0	8.0	42.0	2.0	3.0	50.0
							Canadian zone							
1977	0.0	1.0	17.0	11.0	22.0	196.0	42.0	34.0	23.0	19.0	14.0	2.0	26.0	99.0
1978	0.0	1.0	5.0	47.0	22.0	29.0	186.0	34.0	26.0	17.0	14.0	11.0	2.0	105.0
1979	0.0	1.0	6.0	12.0	81.0	26.0	26.0	148.0	26.0	20.0	13.0	11.0	9.0	88.0
1980	0.0	4.0	1.0	4.0	7.0	43.0	13.0	13.0	72.0	13.0	9.0	6.0	6.0	54.0
1981	0.0	0.0	20.0	3.0	11.0	13.0	52.0	12.0	11.0	60.0	10.0	8.0	6.0	54.0
1982	0.0	6.0	14.0	195.0	19.0	27.0	20.0	61.0	13.0	11.0	61.0	11.0	9.0	72.0
1983	0.0	202.0	29.0	37.0	297.0	20.0	23.0	16.0	48.0	10.0	8.0	49.0	9.0	71.0
1984	0.0	2.0	142.0	16.0	19.0	152.0	10.0	11.0	8.0	24.0	5.0	4.0	26.0	46.0
1985	0.0	0.0	2.0	125.0	12.0	12.0	87.0	5.0	6.0	4.0	12.0	2.0	2.0	43.0
1986	0.0	1.0	2.0	19.0	526.0	29.0	18.0	100.0	5.0	6.0	4.0	12.0	2.0	49.0
1987	0.0	22.0	2.0	1.0	14.0	332.0	16.0	10.0	53.0	3.0	3.0	2.0	7.0	32.0
1988	0.0	0.0	102.0	7.0	4.0	20.0	320.0	13.0	7.0	37.0	2.0	2.0	1.0	34.0
1989	0.0	0.0	0.0	124.0	6.0	3.0	12.0	179.0	7.0	3.0	19.0	1.0	1.0	23.0
							Total population							
1977	295.0	235.0	764.0	174.0	148.0	776.0	134.0	100.0	66.0	53.0	40.0	7.0	74.0	279.0
1978	180.0	230.0	181.0	563.0	122.0	103.0	542.0	94.0	70.0	46.0	38.0	30.0	5.0	278.0
1979	2,162.0	141.0	178.0	133.0	401.0	86.0	72.0	385.0	67.0	50.0	33.0	28.0	23.0	223.0
1980	285.0	1,689.0	108.0	129.0	91.0	270.0	58.0	50.0	264.0	46.0	34.0	23.0	21.0	194.0
1981	355.0	223.0	1,307.0	80.0	93.0	64.0	190.0	40.0	35.0	186.0	32.0	25.0	18.0	168.0
1982	6,258.0	277.0	170.0	951.0	55.0	62.0	42.0	126.0	27.0	22.0	124.0	22.0	18.0	146.0
1983	333.0	4,905.0	213.0	126.0	680.0	39.0	43.0	29.0	87.0	18.0	15.0	88.0	16.0	129.0
1984	76.0	260.0	3,775.0	157.0	90.0	477.0	27.0	29.0	20.0	59.0	12.0	10.0	64.0	114.0
1985	196.0	59.0	201.0	2,838.0	114.0	63.0	330.0	18.0	20.0	13.0	40.0	8.0	7.0	138.0
1986	6,110.0	153.0	46.0	154.0	2,124.0	84.0	46.0	239.0	12.0	14.0	9.0	29.0	5.0	114.0
1987	102.0	4,782.0	118.0	33.0	107.0	1,448.0	56.0	31.0	159.0	8.0	9.0	6.0	21.0	95.0
1988	252.0	79.0	3,668.0	86.0	23.0	71.0	943.0	36.0	19.0	100.0	5.0	6.0	4.0	90.0
1989	903.0	197.0	60.0	2,695.0	59.0	15.0	45.0	596.0	22.0	11.0	61.0	3.0	4.0	73.0

Table 6.10.--Time series of abundance and fishing mortality for Pacific hake. U.S. and Canadian fishing mortality rates are annual rates relative to the portion of the stock in their respective national zones. Abundance is in millions of tons of age-2 and older fish, and is presented at the beginning of the year and the mean within the year. Recruitment is presented as billions of age-2 fish at the beginning of the year (from Dorn et al. 1990).

Year	Beginning biomass	Mean biomass	Beginning spawning biomass	Recruitment (billions)	U.S. fish. mortality	Can. fish. mortality
1958	3.061	2.947	1.398	0.110	0.000	0.000
1959	2.799	2.636	1.335	0.134	0.000	0.000
1960	2.474	2.307	1.216	0.104	0.000	0.000
1961	2.190	2.039	1.054	0.360	0.000	0.000
1962	2.045	1.939	0.920	0.923	0.000	0.000
1963	2.406	2.445	0.847	3.502	0.015	0.002
1964	2.632	2.702	1.003	0.604	0.017	0.002
1965	2.808	2.771	1.143	1.028	0.015	0.002
1966	2.929	2.824	1.260	1.404	0.011	0.003
1967	2.848	2.689	1.214	0.982	0.130	0.003
1968	2.690	2.585	1.134	1.167	0.179	0.133
1969	2.677	2.556	1.118	1.323	0.064	0.228
1970	2.578	2.431	1.084	0.910	0.091	0.341
1971	2.374	2.250	1.017	0.752	0.175	0.252
1972	2.732	2.745	0.966	3.923	0.145	0.092
1973	2.887	2.888	1.125	0.423	0.082	0.152
1974	2.808	2.633	1.193	0.403	0.158	0.050
1975	2.635	2.463	1.169	1.316	0.188	0.057
1976	2.331	2.135	1.047	0.275	0.276	0.052
1977	1.954	1.797	0.888	0.295	0.256	0.019
1978	1.572	1.368	0.743	0.180	0.169	0.012
1979	1.643	1.640	0.628	2.162	0.149	0.026
1980	1.666	1.657	0.657	0.285	0.204	0.050
1981	1.584	1.446	0.659	0.355	0.131	0.084
1982	2.257	2.353	0.613	6.258	0.203	0.132
1983	2.309	2.205	0.796	0.333	0.120	0.228
1984	2.204	2.147	0.902	0.076	0.111	0.349
1985	2.135	2.071	1.030	0.196	0.103	0.295
1986	3.117	2.920	0.883	6.110	0.070	0.119
1987	2.824	2.670	1.013	0.102	0.151	0.236
1988	2.508	2.283	1.029	0.252	0.176	0.301
1989	2.238	1.993	0.994	0.903	0.154	0.426
					0.221	0.413
Avg. 1960-89	2.402	2.298	0.978	1.230	0.125	0.135

Table 6.11.--Parameter values for the age-structured simulation model used to estimate long-term Pacific hake yield (from Dorn et al. 1990).

Age	2	3	4	5	6	7	8	9	10	11	12	13	14	15
USWT	0.280	0.398	0.488	0.566	0.621	0.669	0.720	0.765	0.806	0.863	0.924	0.974	0.992	1.065
CANWT	0.294	0.443	0.603	0.679	0.748	0.788	0.851	0.886	0.915	0.984	1.045	1.090	1.123	1.192
POPWT	0.256	0.388	0.491	0.584	0.651	0.712	0.771	0.827	0.873	0.924	0.976	1.028	1.075	1.117
USSLCT	0.040	0.150	0.420	0.730	0.920	0.980	1.000	0.990	0.970	0.860	0.580	0.240	0.060	0.010
CANSLCT	0.000	0.510	0.560	0.610	0.670	0.740	0.800	0.880	0.950	1.000	0.940	0.680	0.320	0.100
MATURE	0.000	0.500	0.750	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
PROPFEM	0.480	0.501	0.512	0.520	0.524	0.526	0.529	0.536	0.539	0.544	0.553	0.561	0.568	0.575
USCAN	0.000	0.009	0.033	0.087	0.175	0.268	0.329	0.358	0.369	0.373	0.375	0.376	0.376	0.376
POPINIT	0.903	0.197	0.060	2.695	0.059	0.015	0.045	0.596	0.022	0.011	0.061	0.003	0.004	0.073
NMORT	0.237	0.237	0.237	0.237	0.237	0.237	0.237	0.237	0.237	0.237	0.237	0.237	0.237	0.237

USWT - United States fishery weight at age (g)
CANWT - Canadian fishery weight at age (g)
POPWT - Population weight at age (g)
USSLCT - U.S. fishery selectivity at age
CANSLCT - Canadian fishery selectivity at age
MATURE - Proportion of sexually mature females
PROPFEM - Proportion by weight of females in the population
USCAN - Proportion of fish migrating into Canadian zone
POPINIT - Initial population vector (billions)
NMORT - Natural mortality rate

Table 6.12.--Sustainable yield for different management strategies estimated by averaging the results of 20 replicate simulations of the Pacific hake fishery of 1,000 years each. SB_{opt} used in the variable F and hybrid algorithms is defined as the mean female spawning biomass level at a constant F strategy where the probability is 0.20 that the female spawning biomass goes below the cautionary level of female spawning biomass (SB_{caut}) of 457,000 t. The average of the annual F values, reported for the variable and hybrid F strategies, is not equal to F_{opt} because spawning biomass is more frequently below SB_{opt} than above it. Yield and biomass are reported in 1,000 t (kt) (from Dorn et al. 1990).

	F_{opt}	Total yield (kt)	CV	SB_{opt}	Mean F	Spawn. biom. (kt)	CV	% of pristine spawning biomass	% years below SB_{caut}
				Constant F strategy					
Low risk	0.17	168	47.2	---	---	889	44.4	61.8	10.3
Mod. risk	0.24	205	48.0	---	---	782	46.7	54.4	19.8
High risk	0.31	227	49.2	---	---	687	48.9	47.8	30.3
35% prist. spawn. biom.	0.58	278	56.0	---	---	503	57.6	35.0	54.2
				Variable F strategy					
Low risk	0.21	202	74.4	782	0.211	785	38.7	54.6	10.6
Mod. risk	0.31	226	74.1	782	0.274	691	39.9	48.1	20.9
High risk	0.41	247	74.7	782	0.334	637	41.1	44.3	29.7
35% prist. spawn. biom.	0.80	278	77.0	782	0.514	503	44.1	35.0	54.2
				Hybrid strategy					
Low risk	0.22	187	54.8	782	0.189	843	41.8	58.6	9.4
Mod. risk	0.33	221	61.2	782	0.261	728	44.6	50.6	20.3
High risk	0.42	235	64.2	782	0.312	655	44.9	45.6	30.6
35% prist. spawn. biom.	0.82	276	71.8	782	0.507	508	46.4	35.3	54.7

F_{opt} - level of fishing mortality required to achieve the stated management objective

CV - coefficient of variation

Table 6.13.--Summary of information used for the short-term yield forecasts of the Pacific hake resource (from Dorn et al. 1990).

I. Beginning of the year population abundance (billions of fish) by age

Year/Age	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1989	0.903	0.197	0.060	2.695	0.059	0.015	0.045	0.596	0.022	0.011	0.061	0.003	0.004	0.073
1990	1.230	0.707	0.150	0.043	1.811	0.038	0.009	0.028	0.359	0.013	0.007	0.039	0.002	0.060
1991	---	0.961	0.537	0.107	0.029	1.149	0.024	0.006	0.017	0.219	0.008	0.004	0.027	0.048

II. Current weight at age (kg)

Year/Age	2	3	4	5	6	7	8	9	10	11	12	13	14	15
U.S.	0.277	0.370	0.443	0.497	0.540	0.558	0.596	0.633	0.668	0.716	0.796	0.852	0.893	0.928
Canada	0.272	0.573	0.592	0.580	0.677	0.664	0.757	0.811	0.825	0.896	0.993	1.030	1.211	1.226
Popul.	0.284	0.379	0.457	0.520	0.568	0.594	0.633	0.677	0.718	0.757	0.815	0.892	0.972	1.048

1989 estimated yield: U.S.-211,000 t Canada-98,000 t
1990 expected yield: U.S.-196,000 t Canada-73,500 t

1990 beginning of year spawning biomass: 873,000 t
1991 beginning of year spawning biomass: 739,000 t

Table 6.14.--Summary of the 1991-93 potential annual yields. Yield and biomass projections are in thousands of tons. Recruitment scenarios are described in Item VII (from Dorn et al. 1990).

I. Hybrid, low risk strategy (F = 0.22)

II. Constant F, low risk strategy (F = 0.17)

Recruit. scenario	Year	Yield	Spawn. biomass	Age 2+ biomass	Recruit. scenario	Year	Yield	Spawn. biomass	Age 2+ biomass
A	1991	183	738	2,396	A	1991	152	738	2,427
	1992	183	889	2,072		1992	147	905	2,133
	1993	205	895	1,624		1993	168	927	1,713
B	1991	175	738	2,356	B	1991	146	738	2,385
	1992	145	649	2,167		1992	139	664	2,198
	1993	163	806	1,802		1993	131	822	1,858
C	1991	175	738	1,436	C	1991	146	738	1,464
	1992	138	649	2,127		1992	133	664	2,157
	1993	112	565	1,908		1993	123	581	1,923
D	1991	175	738	1,436	D	1991	146	738	1,464
	1992	138	649	1,206		1992	133	664	1,236
	1993	105	565	946		1993	116	581	961

III. Hybrid, moderate risk strategy (F = 0.33)

IV. Constant F, moderate risk strategy (F = 0.24)

Recruit. scenario	Year	Yield	Spawn. biomass	Age 2+ biomass	Recruit. scenario	Year	Yield	Spawn. biomass	Age 2+ biomass
A	1991	265	738	2,317	A	1991	209	738	2,371
	1992	249	849	1,938		1992	195	876	2,039
	1993	272	827	1,445		1993	218	878	1,583
B	1991	253	738	2,282	B	1991	200	738	2,333
	1992	186	610	2,064		1992	183	637	2,110
	1993	208	751	1,669		1993	168	776	1,748
C	1991	253	738	1,361	C	1991	200	738	1,412
	1992	176	610	2,027		1992	174	637	2,072
	1993	135	512	1,802		1993	156	536	1,820
D	1991	253	738	1,361	D	1991	200	738	1,412
	1992	176	610	1,106		1992	174	637	1,151
	1993	125	512	843		1993	145	536	862

Table 6.14.--Continued.

V. Hybrid, high risk strategy (F = 0.42)					IV. Constant F, high risk strategy (F = 0.31)				
Recruit. scenario	Year	Yield	Spawn. biomass	Age 2+ biomass	Recruit. scenario	Year	Yield	Spawn. biomass	Age 2+ biomass
A	1991	327	738	2,257	A	1991	264	738	2,318
	1992	295	819	1,842		1992	236	850	1,953
	1993	313	778	1,322		1993	260	834	1,469
B	1991	311	738	2,226	B	1991	252	738	2,283
	1992	210	581	1,993		1992	221	611	2,031
	1993	229	714	1,587		1993	198	735	1,652
C	1991	311	738	1,305	C	1991	252	738	1,362
	1992	197	581	1,958		1992	208	611	1,997
	1993	146	476	1,734		1993	181	496	1,733
D	1991	311	738	1,305	D	1991	252	738	1,362
	1992	197	581	1,037		1992	208	611	1,076
	1993	134	476	776		1993	168	496	778

VII. Recruitment scenarios

	Year class	Annual recruitment
A.	1989	strong
	1990	weak
	1991	weak
B.	1989	weak
	1990	strong
	1991	weak
C.	1989	weak
	1990	weak
	1991	strong
D.	1989	weak
	1990	weak
	1991	weak

Note: Strong = 3.526 billion (mean of top 25 percent historical recruitment)
Weak recruitment = 0.283 billion (mean of historical recruitment below median)

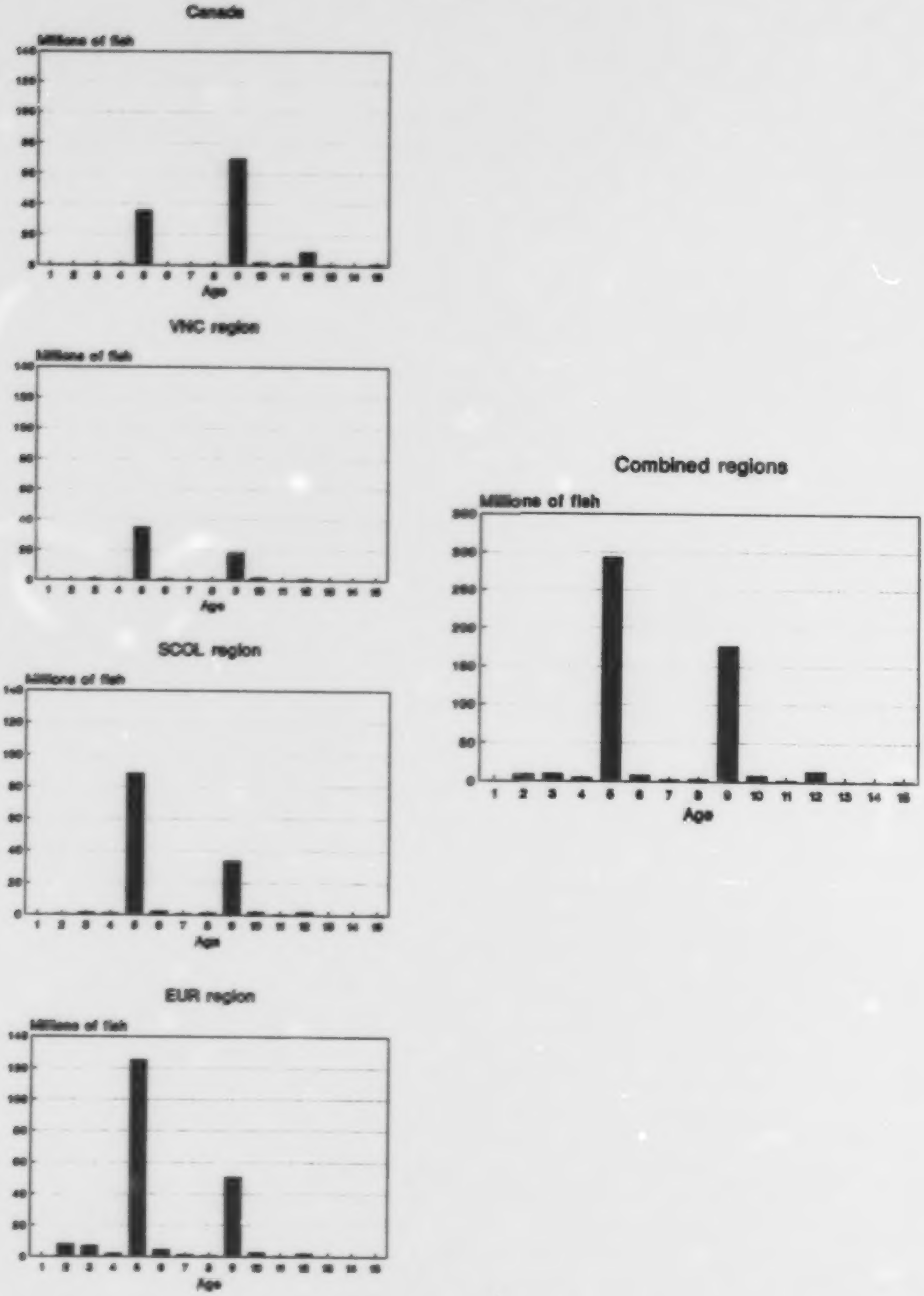


Fig. 6.1. Catch at age by geographic region in millions of fish for the 1989 Pacific hake fishery. VNC=U.S. border -45 deg. 46 min., SCOL=45 deg. 46 min. -43 deg., EUR=43 deg. -39 deg. (from Dorn et al. 1990).

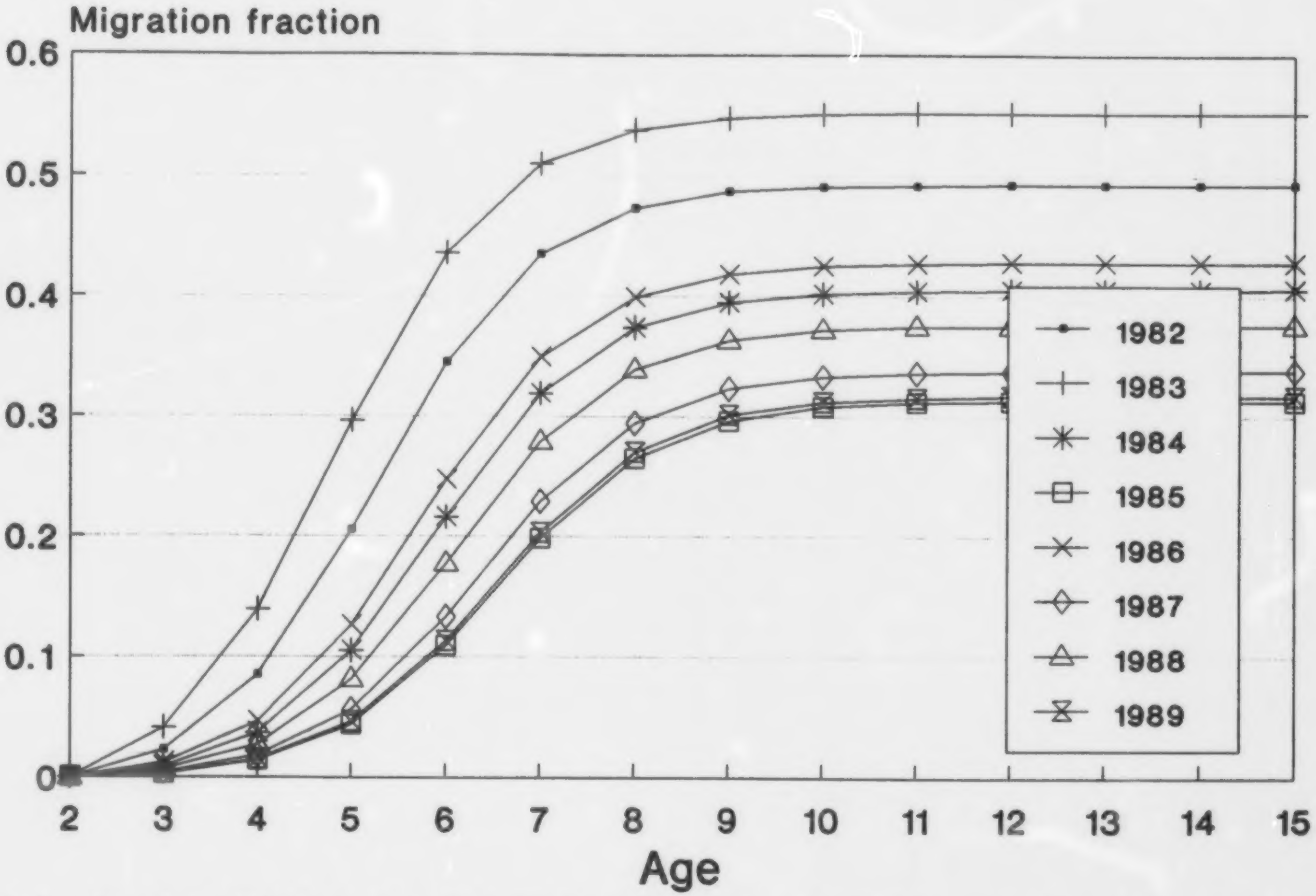


Fig. 6.2. Annual Pacific hake migration curves for 1982-89 estimated by a version of the stock synthesis model incorporating geographic structure. These curves represent the annual age-specific fraction of the population migrating into Canadian waters (from Dorn et al. 1990).

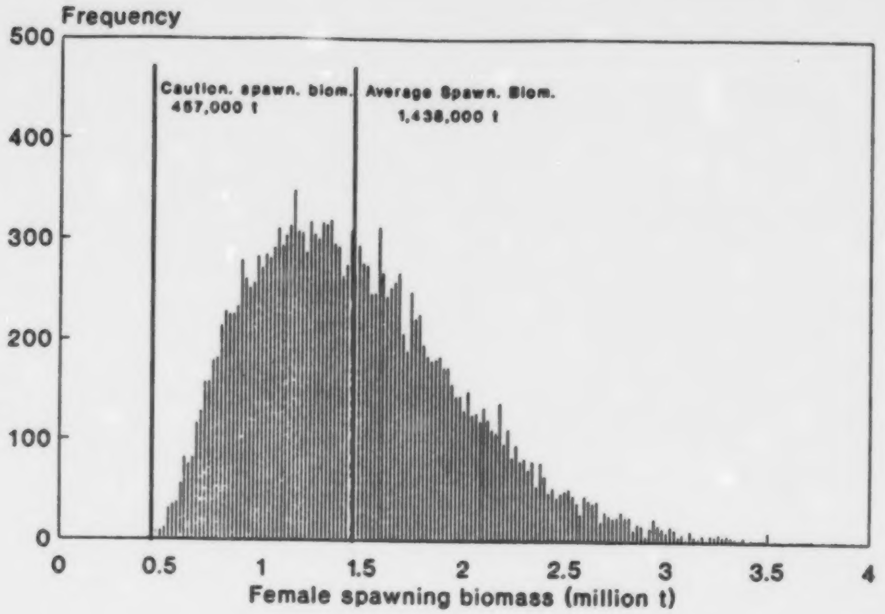


Fig. 6.3. Frequency histogram of female spawning biomass (million t) resulting from 20 replicate 1,000 year simulations of an unexploited Pacific hake population. Recruitments to drive the model were obtained by resampling from the observed recruitment for 1958-87 year classes. A cautionary level of female spawning biomass of 457,000 t was identified as the 0.1 percentile of the empirical distribution of female spawning biomass for an unexploited population (from Dorn et al. 1990).

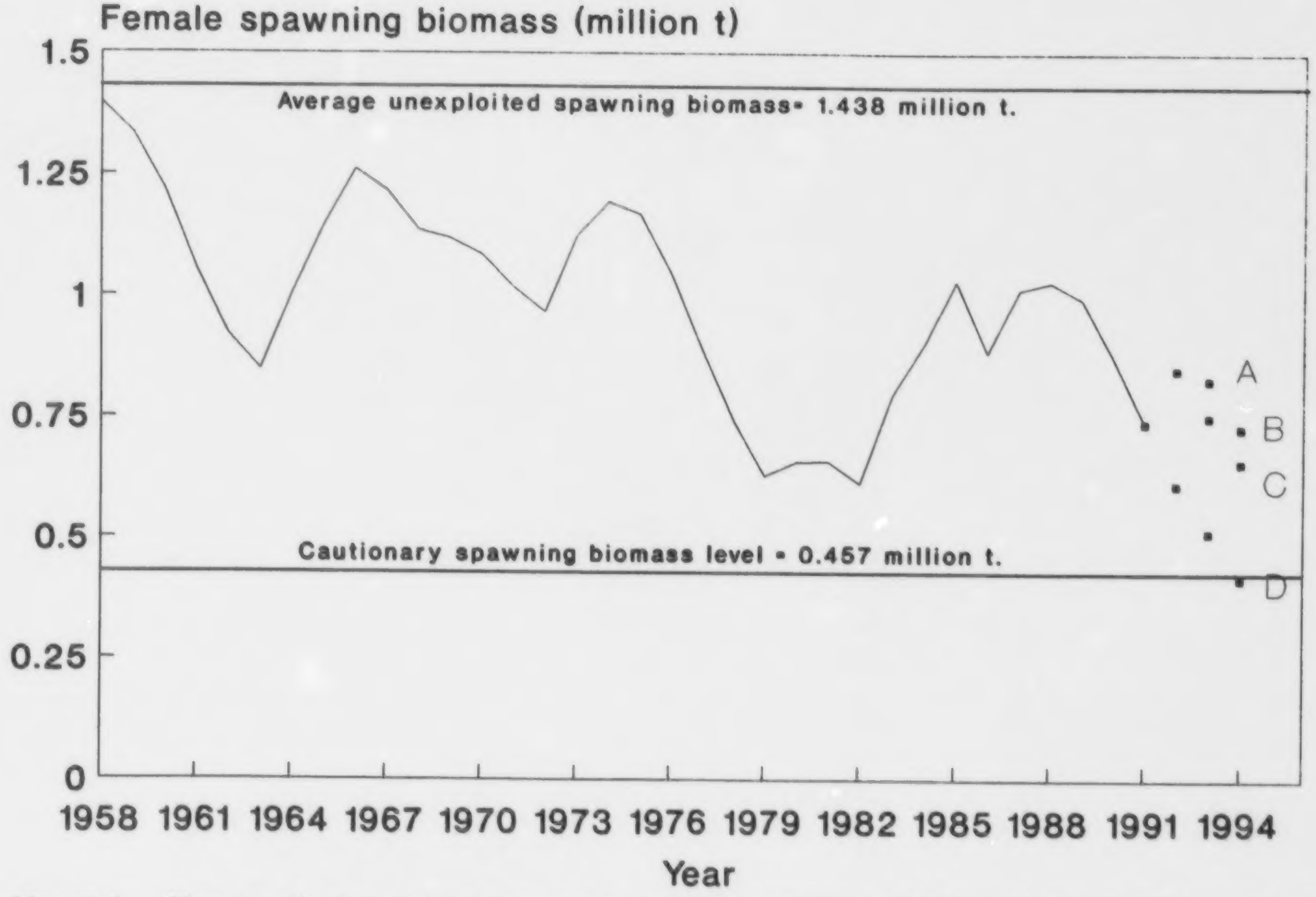


Fig. 6.4. Time trend of Pacific hake female spawning biomass (million t) for 1958-91. The two horizontal lines in the graph indicate the average unexploited female spawning biomass level and the cautionary female spawning biomass level used in the analysis to define risk. The average female spawning biomass from 1958 to 1990 was 0.892 million t. Trajectories A, B, C, and D represent the projected female spawning biomass for 1991-94 with a moderate risk hybrid harvesting strategy (F=.34) under recruitment scenarios A, B, C, and D. (See Table 6.14 for a description of the different recruitment scenarios.) (from Dorn et al. 1990)

7.0 SPINY DOGFISH

by B.L. Thomson, M.W. Saunders
and M.S. Smith

7.1 Coastwide (not including Strait of Georgia)

7.1.1 Introduction

The offshore stock referred to in this assessment ranges from Alaska to California and does not include the Strait of Georgia-Puget Sound stock(s).

7.1.2 Landing Statistics

The offshore commercial catch of spiny dogfish decreased in 1989 to 2109 t from a record high of 4436 t in 1988 (Table 7.1). The dogfish fishery is a marginal fishery that is primarily driven by market value. A decrease in the price paid for dogfish in 1989 is reflected in the lower catches.

The 1990 trawl catch to June 30 was 1172 t, 95% of this from Major Area 3C. The offshore commercial catches have averaged 1766 t over the period 1979-1989. The catch from Major Area 3C has represented approximately 80% of the offshore catch for the past two years. For the 11-year period 1979-1989, Area 3C accounted for an average of 74% of the offshore catch. In the last 3 years, the proportion of catch attributable to longline gear has increased dramatically (Fig. 7.1), largely influenced by increased longline landings from Area 3C (Table 7.1). The effort in the trawl fishery was estimated using effort and catch estimates reported through the logbook system. Effort statistics were not available for the other commercial gears.

Table 7.2 shows longline and trawl catches for Area 3C by quarter. Both fisheries are conducted during the first and second quarters, targetting on the larger, female fish. Landings by the Washington State trawl and longline fisheries remained low (319 t) in 1989 (Table 7.3).

The amount of dogfish used as bait in the commercial prawn fishery has been estimated for the years 1984-1989 using the number of prawn traps fished per year (Table 7.4). After discussions with commercial prawn fisherman, an estimate of one dogfish per 7.5 baited traps was used to calculate the number of dogfish used as bait. Using a field estimate of the average weight of dogfish (2 kg), this was converted to tonnage.

Spiny dogfish remain unexploited off Oregon and California.

7.1.3 Condition of Stock

No new analyses of abundance have been conducted since 1987 (Saunders 1989, 1990). At that time, the coastwide abundance of spiny dogfish was estimated to be 280,000 t. Assuming that one-half to two-thirds of the stock resides off the coast of Canada, the biomass of dogfish in the Canadian zone ranges between 150,000-200,000 t. The stock size is predicted to continue increasing over the next decade, as harvest levels remain low.

7.1.4 Yield Options

Saunders (1989, 1990) discusses detailed options for a sustainable fishery on the offshore spiny dogfish stock. The yield potential for the offshore stock of spiny dogfish under a low risk scenario allows a catch of up to 15,000 t annually, or 9,000 t if the fishery is restricted to the first and second quarters. Current and historic catches remain below this level (Table 7.1).

All options refer to coastwide (including U.S.) removals. No provision has been made for adjusting Canadian catches in the event of increased U.S. catch.

Yield option 1: Sustained yield, no 1st and 2nd quarter fishery

- low risk - 15,000 t
- high risk - 25,000 t

Yield option 2: Sustained yield - first and second quarter fishery, only

- low risk - 9,000 t
- high risk - 15,000 t

Yield option 3: Pulse fishing

The impact of specific pulse fisheries proposed by management can be assessed when proposed. For example, a fishery of 60,000 t taken every five years can be sustained.

7.2 Strait of Georgia - Puget Sound

7.2.1 Introduction

This assessment treats the spiny dogfish from the Strait of Georgia and Puget Sound as a single stock, with an assumed even split of the biomass between the Strait of Georgia and Puget Sound (Saunders 1989, 1990).

7.2.1 Landing Statistics

Total catch of spiny dogfish in 1989 declined to 687 t from 1046 t in 1988. Reduced catches occurred in both longline and trawl fisheries. The American catch of 1098 t was also slightly lower, primarily due to lower longline catches in Area 4A (Table 7.3). The dogfish fishery is a marginal fishery that is primarily driven by market value. In 1989 the price paid for dogfish declined, which is reflected in the lower catches.

The average longline catch for the period 1979-1989 was 1051 t, with a 1989 catch of 528 t. The 1989 trawl catch of 152 t compares to an average catch of 402.7 t over the same 11-year period (Table 7.2). The 1990 trawl catch to June 30 was 87 t.

Sports catch estimates (pieces) were made for Major Area 4B using the Creel survey results from 1981-1989 (Shardlow et al. 1989, Shardlow and Collicutt 1989a-e, Collicutt and Shardlow (in press), Shardlow and Collicutt (in press)). Using a field estimate of the average weight of dogfish (2 kg), these were converted to tonnage of dogfish. Sports catches have been relatively stable and insignificant (Table 7.5). Area 4B accounts for most of the spiny dogfish caught for prawn bait on the coast (Table 7.4). Landings of dogfish for this fishery have increased 2.5 times in the past 5 years.

Both longline and trawl catches are distributed throughout the year. For the past 3 years, first and fourth quarter longline catches have been the strongest.

7.2.2 Condition of the Stock

The assessment of the spiny dogfish stock in the Strait of Georgia is unchanged from Saunders (1989, 1990). Harvest levels remain below 1000 t for the combination of all Canadian fisheries (Tables 2, 4-5). Washington State fisheries are at a similar level (Table 3). At a current biomass estimate of 60,000 t (Saunders 1989, 1990) for the entire stock, abundance should continue to increase.

7.2.3 Yield Options

The yield determined for this stock is as detailed in Saunders (1989, 1990).

The low risk option is 4000 t for the Strait of Georgia-Puget Sound (or 2,000 t for the Strait of Georgia only).

The high risk option is 6000 t for the Strait of Georgia-Puget Sound (or 3,000 t for the Strait of Georgia only).

The combined Canadian and American catches are currently at half the level of the low risk yield.

Table 7.1. Spiny dogfish landings[a] (t) offshore, by Major Area and by gear for 1979-1989.

	3C					3D				5A			
	LL[b]	Trawl[c]		HL&T[d]	Total	LL	Trawl		Total	LL	Trawl		Total
		Catch	Effort				Catch	Effort			Catch	Effort	
1979	4	279	100.3	-	284	5	15	1.9	20	5	10	0.9	15
1980	9	1732	1221.6	-	1742	17	116	37.4	134	5	117	56.8	123
1981	9	285	246.6	-	294	0	17	6.1	17	0	25	11.1	25
1982	0	947	651.5	-	947	3	23	3.8	27	11	14	2.2	25
1983	92	451	227.5	-	543	0	54	18.3	54	16	0	0.0	16
1984	0	455	579.0	-	455	0	3	0.0	3	54	45	7.0	99
1985	0	1365	2498.4	-	1365	60	74	42.9	134	360	52	19.7	412
1986	73	1770	3279.4	-	1843	26	65	9.0	92	74	105	18.9	178
1987	975	972	2026.4	3	1950	128	29	4.4	157	270	66	11.5	336
1988	1883	1643	5500.1	21	3547	159	17	4.6	176	144	86	13.6	230
1989	879	823	4118.2	0	1702	110	28	11.7	138	148	30	9.2	178

	5B					5C					5D			
	LL	Trawl		HL&T	Total	LL	Trawl		HL&T	Total	LL	Trawl		Total
		Catch	Effort				Catch	Effort				Catch	Effort	
1979	0	5	0.9	-	5	1	11	0.5	-	12	22	70	4.9	93
1980	0	39	4.6	-	39	12	59	3.5	-	71	91	242	49.5	333
1981	0	0	0.0	-	0	0	9	1.4	-	9	23	32	5.8	56
1982	0	45	10.9	-	45	3	0	0.0	-	4	49	273	147.0	321
1983	0	9	1.5	-	9	0	3	0.2	-	3	55	17	1.4	72
1984	0	9	2.7	-	9	0	15	28.9	-	15	19	73	17.0	92
1985	38	2	0.9	-	40	0	0	0.0	-	0	18	4	0.3	21
1986	0	0	0.0	-	0	0	1	0.0	-	1	11	9	0.3	20
1987	7	2	0.0	0	9	223	1	0.0	0.2	225	55	2	0.1	57
1988	114	0	0.0	0	114	300	2	0.2	0	302	25	0	0.0	25
1989	44	0	0.0	0.8	45	45	0	0.0	0.1	45	0	3	0.3	3

[a] Source: Groundfish data files (includes logbook and saleslip information).

[b] LL = longline.

[c] Trawl landings exclude dumped and discarded fish, trawl effort (hours) estimated from logbook information.

[d] HL&T = handline and troll, data begin 1987.

Table 7.1 (cont.). Spiny dogfish landings[a] (t) offshore, by Major Area and by gear for 1979-1989.

	5E					Total Offshore				
	LL[b]	Trawl[c] Catch	Trawl[c] Effort	HL&T[d]	Total	LL	Trawl Catch	Trawl Effort	HL&T	Total
1979	0	0	0.0	-	0	37	390	348.1	-	428
1980	0	1	0.0	-	1	136	2306	1477.5	-	2442
1981	0	0	0.0	-	0	33	367	331.2	-	400
1982	20	0	0.0	-	20	86	1302	937.5	-	1388
1983	10	0	0.0	-	10	173	533	464.9	-	706
1984	3	0	0.0	-	3	76	600	838.5	-	676
1985	0	0	0.0	-	0	476	1496	2988.8	-	1972
1986	0	0	0.0	-	0	184	1951	3636.2	-	2135
1987	1	0	0.0	0	1	1659	1072	2156.9	3	2735
1988	41	0	0.0	1.6	43	2666	1748	5560.7	23	4436
1989	0	0	0.0	0	0	1226	883	4175.9	1	2110

[a] Source: Groundfish data files (includes logbook and saleslip information).

[b] LL = longline.

[c] Trawl landings exclude dumped and discarded fish, trawl effort (hours) estimated from logbook information.

[d] HL&T = handline and troll, data begin 1987.

Table 7.2. Dogfish landings[a] (t) for Major Area 4B and 3C, by gear and quarter for 1979-1989.

	Area 4B														
	Longline					Trawl[b]						HL&T[c]	Sports[d]	Bait[e]	
	Quarter					Quarter									Grand Total
	I	II	III	IV	Total	I	II	III	IV	Total	Trawl Effort	Total	Total	Total	
1979	822	216	429	2120	3587	99	8	106	669	882	238.6	-	-	-	4468
1980	810	507	23	229	1569	288	34	0	242	564	104.2	-	-	-	2133
1981	5	2	0	499	506	88	0	0	182	270	60.2	-	5	-	781
1982	319	68	6	471	865	100	28	120	171	420	122.1	-	14	-	1298
1983	270	176	55	336	837	81	111	70	173	434	216.0	-	9	-	1280
1984	353	260	347	638	1598	26	80	111	82	299	203.9	-	9	85	1991
1985	279	118	4	44	446	166	171	9	78	424	426.7	-	9	84	962
1986	70	17	0	0	87	114	116	16	147	393	328.6	-	10	122	612
1987	211	44	33	425	714	95	94	77	103	368	114.5	2	8	155	1247
1988	598	162	4	60	824	90	67	30	33	221	42.2	2	8	145	1199
1989	78	39	15	395	528	36	23	52	41	152	36.6	8	7	160	854

[a] Source: Groundfish data files (includes logbook and saleslip information).

[b] Trawl landings exclude dumped or discarded fish, trawl effort (hours) estimated from logbook information.

[c] HL&T = handline and troll, data begin 1987.

[d] Source: Collicutt and Shardlow (in press), Shardlow et al. 1989, Shardlow and Collicutt 1989a-e, Shardlow and Collicutt (in press); data begin 1981.

[e] Source: Shellfish data files, data begin 1984.

Table 7.2 (cont.). Dogfish landings[a] (t) for Major Area 4B and 3C, by gear and quarter for 1979-1989.

Area 3C														
	Longline					Trawl[b]						HL&T[c]	Bait[e]	
	Quarter					Quarter								
	I	II	III	IV	Total	I	II	III	IV	Total	Trawl Effort	Total	Total	Grand Total
1979	3	0	0	1	4	2	200	49	28	279	100.3	-	-	283
1980	2	7	0	0	9	512	1111	109	0	1732	1221.6	-	-	1742
1981	0	0	0	9	9	37	208	17	24	285	246.6	-	-	294
1982	0	0	0	0	0	209	612	82	44	947	651.5	-	-	947
1983	0	83	9	0	92	180	147	50	73	450	227.5	-	-	543
1984	0	0	0	0	0	241	126	66	22	455	579.0	-	2	457
1985	0	0	0	0	0	498	741	41	85	1365	2498.4	-	0	1365
1986	55	17	0	0	73	729	883	13	146	1770	3279.4	-	0	1843
1987	169	507	71	228	975	486	440	0	45	972	2026.4	3	1	1951
1988	801	1058	2	22	1883	337	1303	3	0	1643	5500.1	21	1	3548
1989	378	448	0	54	879	72	718	0	33	823	4118.2	0	6	1709

[a] Source: Groundfish data files (includes logbook and saleslip information).
[b] Trawl landings exclude dumped or discarded fish, trawl effort (hours) estimated from logbook information.
[c] HL&T = handline and troll, data begin 1987.
[d] Source: Collicutt and Shardlow (in press), Shardlow et al. 1989, Shardlow and Collicutt 1989a-e, Shardlow and Collicutt (in press); data begin 1981.
[e] Source: Shellfish data files, data begin 1984.

Table 7.3. Dogfish landings[a] (t) by gear from Washington State.

		Trawl	Longline	Other	Total
1983					
	Inshore[b]	856	435	-	1291
	Offshore[c]	21	5	-	26
1984					
	Inshore	753	504	188	1445
	Offshore	239	79	-	318
1985					
	Inshore	469	363	139	971
	Offshore	172	101	1	274
1986					
	Inshore	304	325	117	746
	Offshore	83	29	1	113
1987					
	Inshore	373	721	335	1429
	Offshore	91	893	-	984
1988					
	Inshore	371	798[d]	227[d]	1396
	Offshore	133	67[d]	.4[d]	200
1989					
	Inshore[d]	350	549	199	1098
	Offshore[d]	82	237	.2	319

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[a] Source: Technical Sub-committee, Washington State Status Reports, unpublished text.

[b] Inshore = Major Area 4A.

[c] Offshore = all Major Areas excluding 4A.

[d] Source: State of Washington, Department of Fisheries.

Table 7.4. Spiny dogfish[a] (t) used as trap[b] bait in commercial prawn fishery.

	5B	5C			5B				5A	3D				3C
Subarea[c]	07	06	02	Total	08	09	10	Total	11	25	26	27	Total	23
1984	0.6	1.0	0.0	1.0	1.4	1.0	0.6	3.0	1.4	0.9	0.4	0.3	1.6	2.0
1985	0.7	0.1	0.0	0.1	2.3	2.0	0.1	4.4	0.0	0.8	0.3	0.7	1.8	0.1
1986	1.6	3.0	0.0	3.0	4.3	0.9	0.0	5.2	0.0	1.0	0.0	0.3	1.3	0.0
1987	6.0	0.9	1.9	2.8	8.7	4.7	1.7	15.1	1.9	2.6	0.7	0.1	3.3	0.6
1988	24.2	4.2	0.7	5.0	11.1	8.1	1.1	20.3	0.7	2.2	0.9	1.0	4.0	0.7
1989[d]	16.3	18.9	0.1	19.0	14.3	6.9	5.0	26.2	4.9	8.0	9.1	4.1	21.2	6.3

	4B											B.C.
Subarea	12	13	14	15	16	17	18	19	20	28/29	Total	Total
1984	2.5	6.1	6.7	24.0	16.4	20.2	0.2	1.1	0.0	7.9	85.2	94.6
1985	13.9	2.7	9.0	22.5	10.9	21.5	0.7	0.0	0.0	2.3	83.5	90.6
1986	17.7	4.3	8.4	35.4	18.4	29.0	0.4	3.4	0.0	4.8	121.6	132.7
1987	16.4	20.9	16.0	42.9	30.0	20.7	1.3	1.8	0.0	5.1	155.1	184.7
1988	24.1	11.6	16.7	36.5	26.8	24.0	2.1	2.1	0.0	1.3	145.1	200.0
1989[d]	31.7	21.9	12.3	30.6	39.3	14.1	1.4	2.4	0.4	5.4	159.5	253.4

[a] Estimated 7.5 baited traps/spiny dogfish, mean spiny dogfish size of 80 cm (2.0 kg).

[b] Source: Shellfish data files, data begin 1984.

[c] Fisheries Branch Managment Area.

[d] Number of baited traps estimated from mean percentage of traps baited with spiny dogfish 1985-1988 out of total traps fished.

Table 7.5. Total spiny dogfish landings (t) in B.C. by gear.

	Longline[a]			Trawl[a]			HL&T[ab]	Bait[c]	Sports[d]	Total
	Inshore	Offshore	Total	Inshore	Offshore	Total				
1979	3587	37	3624	882	390	1272	-	-	-	4896
1980	1569	136	1705	564	2306	2870	-	-	-	4575
1981	506	33	539	270	367	637	-	-	5	1181
1982	865	86	951	420	1302	1722	-	-	14	2687
1983	837	173	1010	434	533	967	-	-	9	1986
1984	1598	76	1674	299	600	899	-	95	9	2677
1985	446	476	922	424	1496	1920	-	91	9	2942
1986	87	184	271	393	1951	2344	-	133	10	2758
1987	714	1659	2373	368	1072	1440	5	185	8	4011
1988	824	2666	3490	221	1748	1969	25	200	8	5692
1989	528	1226	1754	152	883	1035	9	253	7	3059

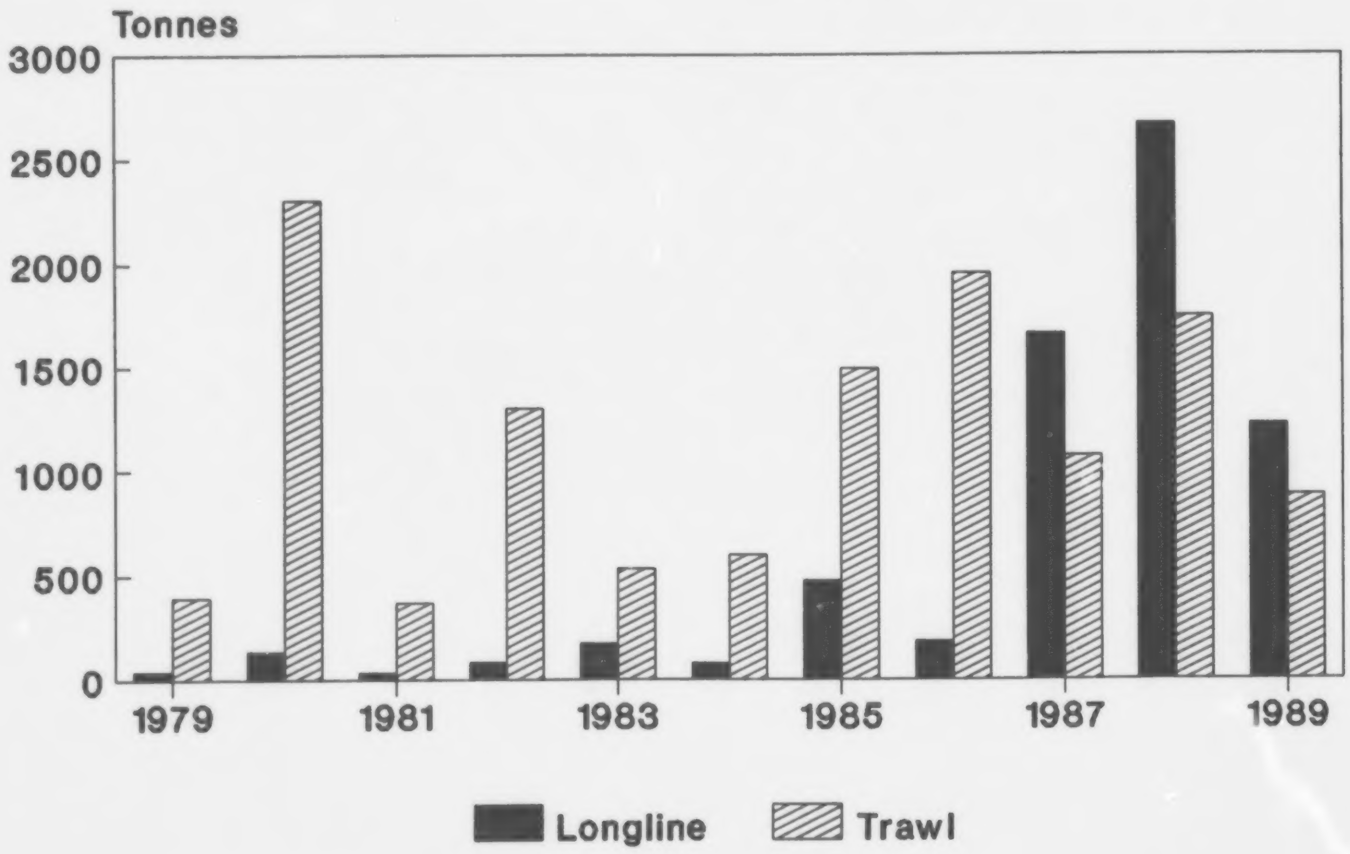
[a] Source: Groundfish data files (includes logbook and saleslip information).

[b] HL&T = handline and troll, data begin 1987.

[c] Source: Shellfish data files, data begin 1984.

[d] Source: Collicutt and Shardlow (in press), Shardlow et al. 1989, Shardlow and Collicutt 1989a-e, Shardlow and Collicutt (in press); data begin 1981.

Figure 7.1 Spiny Dogfish Offshore Catch (t) by Gear



8.0 WALLEYE POLLOCK

by G. Workman and M. Saunders

8.1.1 Coastwide

Yield options are not proposed on a coastwide basis.

8.2. Strait of Georgia

8.2.1. Introduction

Walleye pollock is an abundant resident fish cohabiting with Pacific hake in the Strait of Georgia. The fishery has remained small over the past years as a result of weak markets. Pollock is a relatively small gadid and the cost of processing is one of the factors limiting price. Larger pollock are processed into frozen fillets while smaller pollock are headed and gutted, both products are marketed as Bigeye Cod. Pollock is used as a substitute for Pacific cod fillets when cod landings are low.

The 1990 assessment incorporates changes that reflect the greater longevity of these fish demonstrated by McFarlane and Beamish (in press).

8.2.2. Landing statistics

During 1989, a total of 509 t was landed, a decrease of 45.7% from the 1988 landings (Table 8.1). The landings were predominantly (99.9%) from trawlers using mid-water gear (Table 8.2). The majority (94.5%) of the landings were made in the first quarter.

8.2.3. Condition of stock

The size composition data for 1987 through spring 1990 (Figs. 8.1-8.4) indicate successive year classes have dominated the catch. The modal length in 1987 was 40 cm with a mean of 41 cm. In 1988 a new year class recruited to the fishery, modes occurred at 37-39 and 43-46 cm. It is possible to infer ages for the younger of these fish from the age-length data presented by Thompson (1981) (Fig. 8.5). In 1987 the catch was dominated by age 4 fish. In 1988, the inferred dominant ages would be three and five. No samples were taken in 1989. Length frequency samples collected early in 1990 show modes at 34 cm and 42 cm which indicated a population dominated by age 2 and 5. This suggests recruitment with smaller younger fish comprising 50 % of the catch.

The previous assessment (Saunders 1990) was based on estimates of maximum sustainable yield (MSY) using Gulland's (1970) relationship of MSY = a(M)(B). The following parameter estimates used in the equation were: natural mortality (M) of 0.5-0.7; value of (a) of 0.3-0.5; and a biomass (B) estimate of 15,800-29,400 t (Shaw et al. 1985).

McFarlane and Beamish (in press) demonstrated the superiority of otoliths over scales and fin ray sections in detecting older individuals in offshore populations. In light of these findings the natural mortality rates used previously to calculate the MSY are likely to high. A study is under way to determine the natural mortality rates for Strait of Georgia pollock. Given the observed age structure a more appropriate value should fall in the range of .2-.5. This value is between the values known for other longer and shorter lived gadids such as Pacific hake and Pacific cod, respectively. The estimates of (a) remain unchanged. The hydroacoustic and swept-volume trawl surveys conducted in 1988 indicate that the biomass still falls within the above range (Shaw et al. 1989).

8.2.4. Yield options

The conservative level is based on the lower level of unexploited biomass (15,800 t), a natural mortality of M=0.3, and a constant (a) value of 0.3. The high risk level is based on a midpoint of the biomass estimate (22,600 t), a midpoint in the natural mortality estimate M=0.4 and a constant value of a=0.4, which Gulland (1983) indicated as a realistic value for gadid-like species.

Yield options may be chosen from:

Yield option 1: Conservative sustainable - 1500 t

Yield option 2: Risk sustainable - 3700 t

8.3. West Coast Vancouver Island

8.3.1. Introduction

Walleye pollock remain a small incidental catch in the joint venture and foreign Pacific hake fishery off the west coast of Vancouver Island (Area 3C and 3D). Small quantities of pollock are caught incidentally by the domestic fleet while targeting on other groundfish species in Areas 3C and 3D.

8.3.2. Landing statistics

The landings by joint venture and foreign fleet in 1989 increased from 252 t in 1988 to 907 t (Table 8.3). The majority (99%) of these landings were from the joint venture fishery.

The domestic fleet reported a catch of 33 t of pollock from Area 3C (Table 8.1).

8.3.3 Condition of stock.

Hake observers aboard foreign factory trawlers have provided biological data on the by-catch of pollock off the west coast since 1987. Length frequency data (Figs. 8.6-8.8) from 1987 through 1989 show a succession of year classes passing through the fishery. In 1987 and 1988 the modal lengths were 35 cm and 41 cm and means were 38 cm and 43 cm. In 1989 a year class recruited to the population producing length frequencies with modes at 32 cm and 46 cm. If one assumes the length-at-age relationship for these fish is similar to that of pollock in Queen Charlotte Sound, it is possible using the data of Thompson (1981) (Fig. 8.9) to infer ages for the younger fish in the population. In 1987, the population was dominated by two year olds; in 1988, the same year class remained dominant as three year olds. In 1989 two year olds dominated however fish aged four and older remain a large component of the catch.

8.3.4. Yield options

The yield options remain unchanged from the previous assessment (Shaw et al. 1985).

Yield option : unrestricted yield.

8.4 Queen Charlotte Sound

Yield options are not proposed for this region.

8.5. Hecate Strait

8.5.1. Introduction

The walleye pollock fishery in northern Hecate Strait and Dixon Entrance (Areas 5C and 5D), occurs mainly in the winter months, from November to December, when fish are processed into fillets and act as a substitute for Pacific cod. There is little demand for pollock fillets and no demand for roe. The markets have not improved since the late 1970's. This is in part due to the large pollock fishery in the Gulf of Alaska, which has dominated the market for both roe and fillets.

The 1990 assessment remains unchanged from Shaw et al. (1985).

8.5.2. Landing statistics

Pollock landings in 1989 increased to 28 t from 10 t reported for 1988 (Table 8.4). All landings were from Major Area 5D.

8.5.3 Condition of stock

The status of this stock is currently unknown since there has been neither an active fishery nor research cruises conducted since the late 1970's. Recent review of evidence for stock delineation of pollock in Canadian waters (Saunders et al. 1989) suggests that the stock ranges throughout southeast Alaska, Dixon Entrance and Hecate Strait. Should industry interest grow, the stock should be re-assessed and, until that time, yield remain unrestricted.

Biological data are very limited for this stock. Length frequency data collected in 1990 (Fig. 8.10-8.11), from Major area 5D, indicate a population of large fish. All catches occurred in the first and fourth quarters and all fish were mature or maturing. This is consistent with findings of Saunders et al. (1989); who concluded that the fishery in Dixon entrance occurred on only the spawning stock of adult fish.

8.5.4. Yield options

The yield options remain unchanged from the previous assessment (Shaw et al. 1985). The catch is currently limited due to weak markets.

Yield option : Unrestricted yield.

8.6.1 West Coast of Queen Charlotte Islands

Yield options are not proposed for this region.

Table 8.1. Total landings (t) of walleye pollock by the domestic fleet by major statistical area, 1954-88.

	Landings (t)									
Year	4B	3B	3C[a]	3D	5A	5B	5C	5D	5E	Total
1954	147	0	3	0	13	1	0	0	0	164
1955	418	0	5	0	1	0	0	3	0	427
1956	380	0	52	0	5	0	0	14	0	451
1957	248	0	4	0	3	0	0	7	0	262
1958	121	0	0	0	.3	0	0	14	0	135
1959	260	0	8	0	.4	0	0	2	0	270
1960	95	0	5	0	1	3	0	10	0	114
1961	115	0	.1	0	1	0	.3	7	0	123
1962	49	0	6	0	0	0	0	12	0	67
1963	13	0	7	0	6	0	0	4	0	30
1964	33	0	2	0	5	0	0	2	0	42
1965	26	0	10	0	0	0	0	9	0	45
1966	37	0	.4	0	1	.1	.4	82	0	121
1967	33	0	0	0	1	0	7	48	0	89
1968	16	0	2	0	7	0	4	13	0	42
1969	30	0	14	0	33	0	0	47	0	124
1970	45	0	0	0	0	0	0	8	0	53
1971	80	0	5	0	0	0	0	0	0	85
1972	71	0	.3	0	172	0	0	1	0	244
1973	9	0	.1	0	62	9	.4	13	0	94
1974	11	0	0	0	6	6	2	47	0	72
1975	1	0	0	0	21	10	1	70	0	103
1976	26	0	5	2	69	400	193	627	.2	1322
1977	50	0	10	0	61	175	16	567	12	891
1978	380	0	6	.4	106	187	11	1700	21	2411
1979	1341	0	31	.3	72	71	238	1566	67	3386
1980	1056	0	3	3	12	23	83	1103	18	2301
1981	570	0	8	1	2	10	79	563	22	1255
1982	100	0	10	0	1	6	3	808	1	929
1983	25	0	3	1	11	10	6	986	28	1070
1984	157	0	5	0	11	7	2	625	< .1	807
1985	748	0	4	0	0	1	0	1176	2	1931
1986	469	0	3	0	0	0	0	95	0	567
1987	1237	0	0	0	29	5	0	4	0	1275
1988	1095	0	3	0	2	2	0	10	0	1112
1989	442	0	33	0	2	4	0	28	0	509

[a] Excludes incidental landings by the foreign fleet participating in the offshore Pacific hake fishery during 1980 to 1988.

Table 8.2. Walleye pollock landings by gear type and by quarter from the Strait of Georgia (Major Area 4B), 1976-1988.

		Major Area 4B		
Year		Quarter 1	Quarter 4	Total
1976	MWT [a]	-	-	0
	BT [b]	3	23	26
	Total	3	23	26
1977	MWT	-	-	0
	BT	24	26	50
	Total	24	26	50
1978	MWT	177	-	177
	BT	142	41	183
	Total	319	41	360
1979	MWT	1033	3	1036
	BT	283	20	303
	Total	1316	23	1339
1980	MWT	841	-	841
	BT	189	23	212
	Total	1030	23	1053
1981	MWT	455	-	455
	BT	99	5	104
	Total	554	5	559
1982	MWT	81	-	81
	BT	8	7	15
	Total	89	7	96
1983	MWT	19	-	19
	BT	3	2	5
	Total	22	2	24
1984	MWT	8	90	98
	BT	-	2	2
	Total	8	92	100
1985	MWT	401	319	720
	BT	5	19	24
	Total	406	338	744

Table 8.2. (cont'd)

		Major Area 4B		
Year		Quarter 1	Quarter 4	Total
1986				
	MWT	162	294	456
	BT	10	2	12
	Total	172	296	468
1987				
	MWT	1118	56	1174
	BT	3	15	18
	Total	1121	71	1192
1988				
	MWT	1060	31	1091
	BT	2	2	4
	Total	1062	33	1095
1989				
	MWT	419	23	442
	BT	0	0	0
	Total	419	23	442

[a]MWT = Midwater trawl.
[b]BT = Bottom trawl.

Table 8.3. Incidental catches of walleye pollock by joint venture and foreign fleets participating in the offshore hake fishery off west coast Vancouver Island (Major Area 3C), 1980-1988. (Catch statistics from Offshore Division, Vancouver.)

		Landings (t)		
Year	Nations	National[a]	Joint venture	Total
1980	Poland	487	236	
	USSR	63	584	
	Japan	142	0	
	Greece	-	175	
	Total	692	995	1687
1981	Poland	131	205	
	USSR	26	299	
	Japan	9	0	
	Greece	-	285	
	Total	166	789	955
1982	Poland	468	222	
	USSR	0	149	
	Japan	38	-	
	Total	506	371	877
1983	Poland	13	6	
	USSR	-	-	
	Total	13	6	19
1984	Poland	1	66	
	USSR	-	41	
	Total	1	107	108

Table 8.3. (cont'd)

		Landings (t)		
Year	Nations	National[a]	Joint venture	Total
1985	Poland	2	78	
	Total	2	78	80
1986	Poland	14	19	
	USSR	1	63	
	Total	15	82	97
1987	Poland	82	693	
	USSR	31	480	
	Korea	-	65	
	Total	113	1238	1351
1988	Poland	1	195	
	USSR	0	56	
	Japan	-	0	
	Total	1	251	252
1989	Poland	8	442	
	USSR	1	409	
	Japan	-	47	
	Total	9	898	907

[a] "National" landings include landings from the supplementary fishery.

Table 8.4. Walleye pollock landings by gear type and by quarter from Major Areas 5C and 5D, 1976-1988.

		Major Area 5C				Major Area 5D			
Year		Quarter1	Quarters2,3	Quarter4	Total	Quarter1	Quarter2,3	Quarter4	Total
1976	MWT[a]	-	25	102	127	-	208	56	264
	BT[b]	<1	19	47	66	5	141	214	360
	Total	<1	44	149	193	5	349	270	624
1977	MWT	-	-	-	0	<1	<1	-	<1
	BT	1	14	1	16	34	509	24	567
	Total	1	14	1	16	34	509	24	567
1978	MWT	-	1	-	1	425	299	71	795
	BT	1	7	2	10	107	657	141	905
	Total	1	8	2	11	532	956	212	1700
1979	MWT	-	-	-	0	593	52	11	656
	BT	1	103	134	238	119	521	270	910
	Total	1	103	134	238	712	573	281	1566
1980	MWT	-	<1	-	<1	201	261	9	471
	BT	1	73	9	83	116	482	34	632
	Total	1	73	9	83	317	743	43	1103
1981	MWT	-	-	-	0	61	-	79	140
	BT	27	21	31	79	71	248	104	423
	Total	27	21	31	79	132	248	183	563
1982	MWT	-	-	-	0	2	-	607	609
	BT	<1	3	<1	3	4	98	97	199
	Total	<1	3	<1	3	6	98	704	808
1983	MWT	-	-	-	0	-	34	784	818
	BT	-	6	-	6	43	46	79	168
	Total	0	6	0	6	43	80	863	986
1984	MWT	-	-	-	0	301	-	266	567
	BT	-	2	-	2	13	40	5	58
	Total	0	2	0	2	314	40	271	625

Table 8.4. (cont')

		Major Area 5C				Major Area 5D			
	Year	Quarter1	Quarters2,3	Quarter4	Total	Quarter1	Quarter2,3	Quarter4	Total
1985	MWT	-	-	-	0	369	0	754	1123
	BT	-	-	-	0	10	42	1	53
	Total	0	0	0	0	379	42	755	1176
1986	MWT	-	-	-	0	66	0	2	68
	BT	-	-	-	0	8	18	1	27
	Total	0	0	0	0	74	18	3	95
1987	MWT	-	-	-	0	1	1	-	2
	BT	-	-	-	0	-	2	-	2
	Total	0	0	0	0	1	3	0	4
1988	MWT	0	0	0	0	0	0	0	0
	BT	0	3	0	3	2	0	8	10
	Total	0	3	0	3	2	0	8	10
1989	MWT	0	0	0	0	0	0	6	6
	BT	0	0	0	0	10	12	0	22
	Total	0	0	0	0	10	12	6	28

[a] MWT = Midwater trawl.
[b] BT = Bottom trawl.

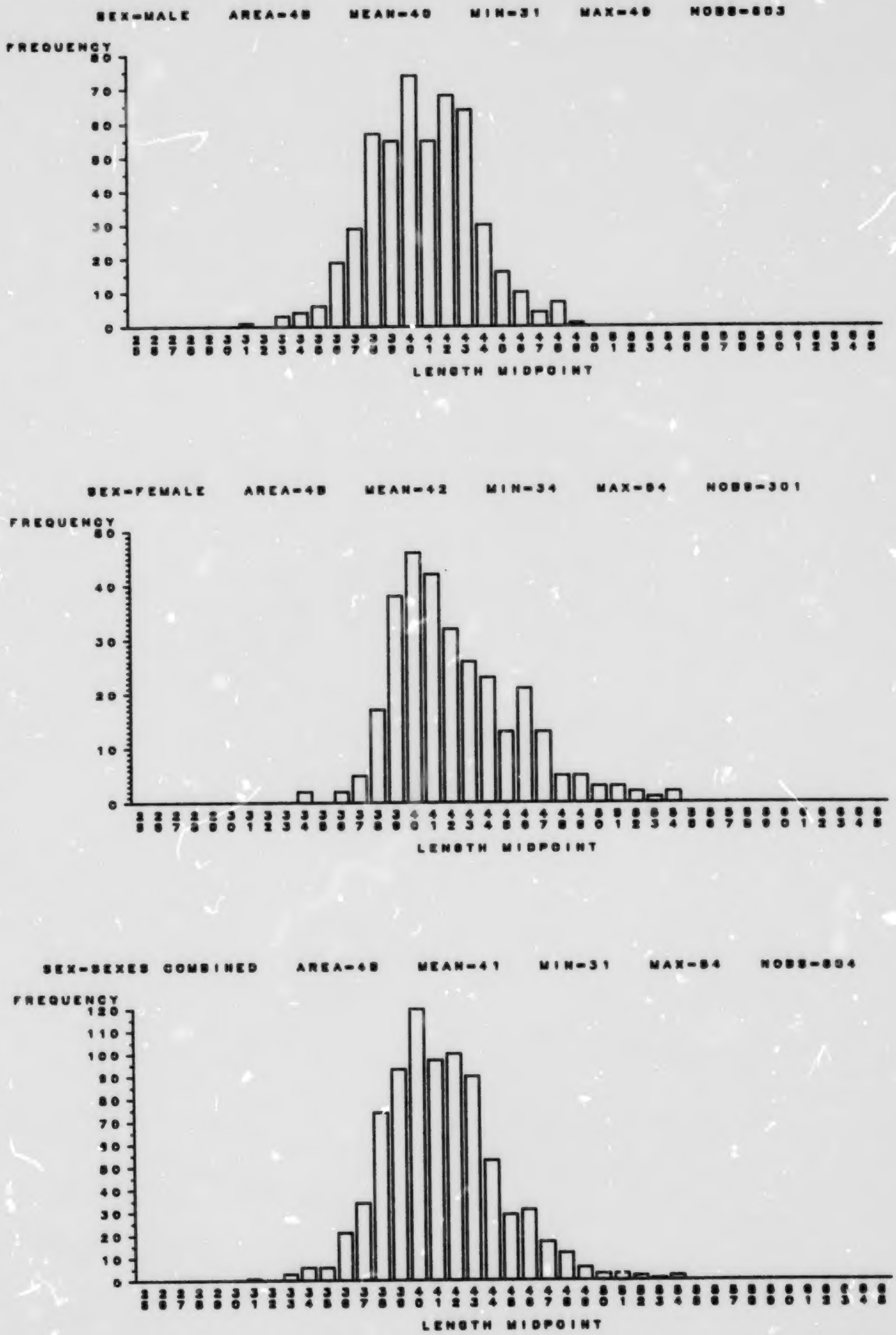


Fig. 8.1. Length frequencies for male, female and sexes combined port sampled pollock from Major area 4B, Strait of Georgia, for 1987.

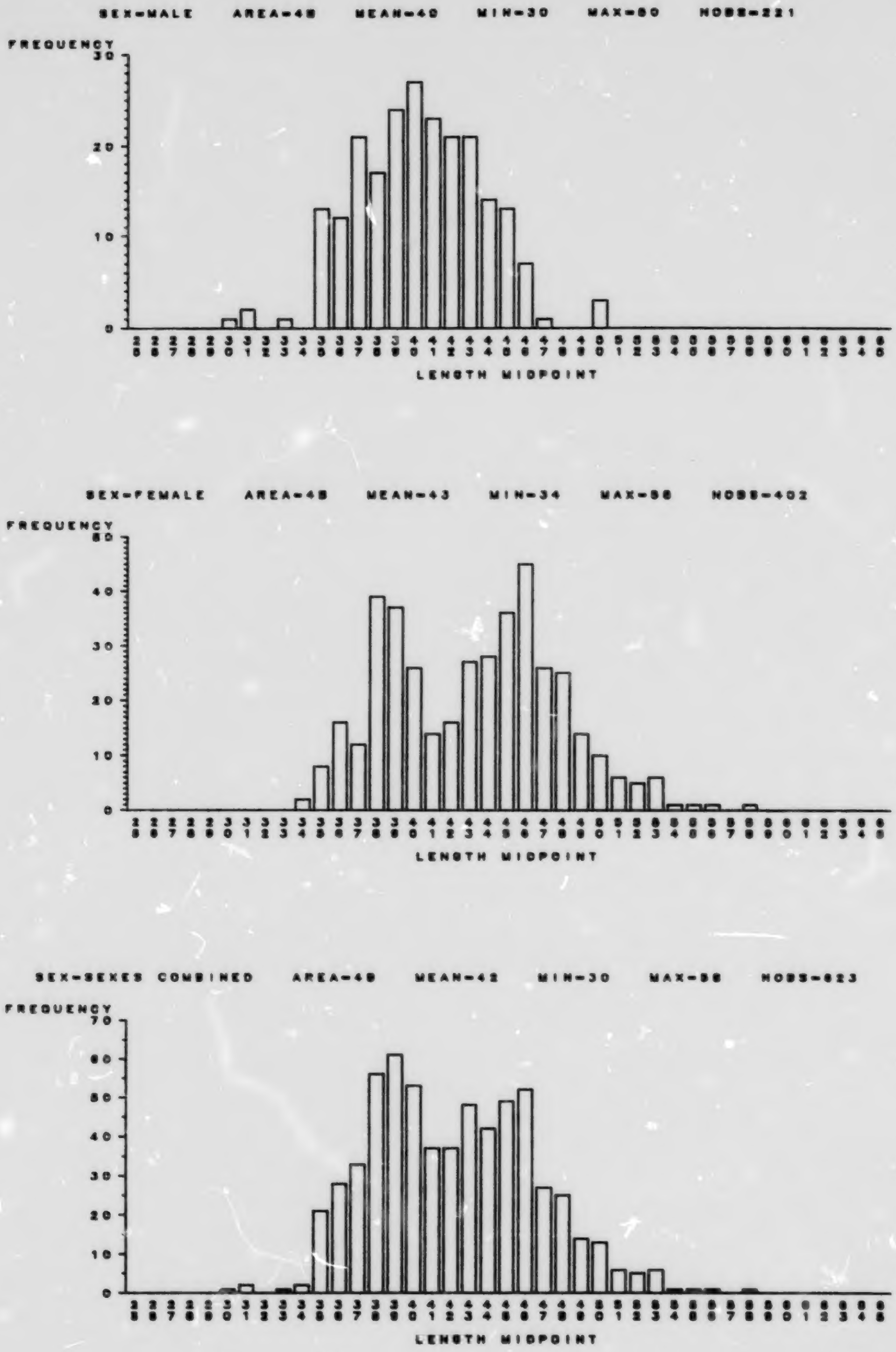


Fig. 8.2. Length frequencies for male, female and sexes combined port sampled pollock from Major area 4B, Strait of Georgia, for 1988.

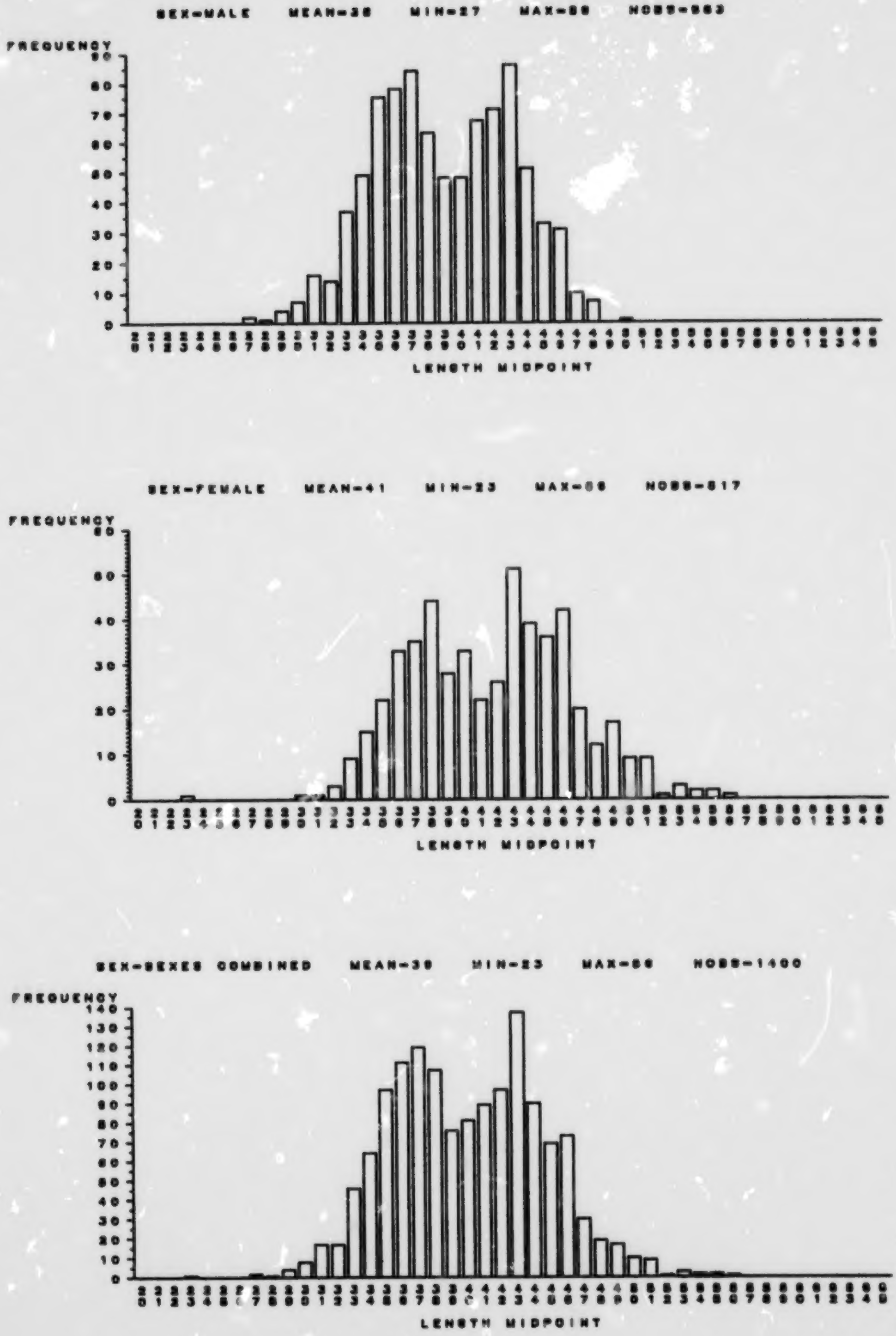


Fig. 8.3. Length frequencies for male, female and sexes combined pollock sampled aboard the W.E. Ricker in the Strait of Georgia (Major area 4B) during the 1988 hydroacoustic/swept volume stock assessment cruise.

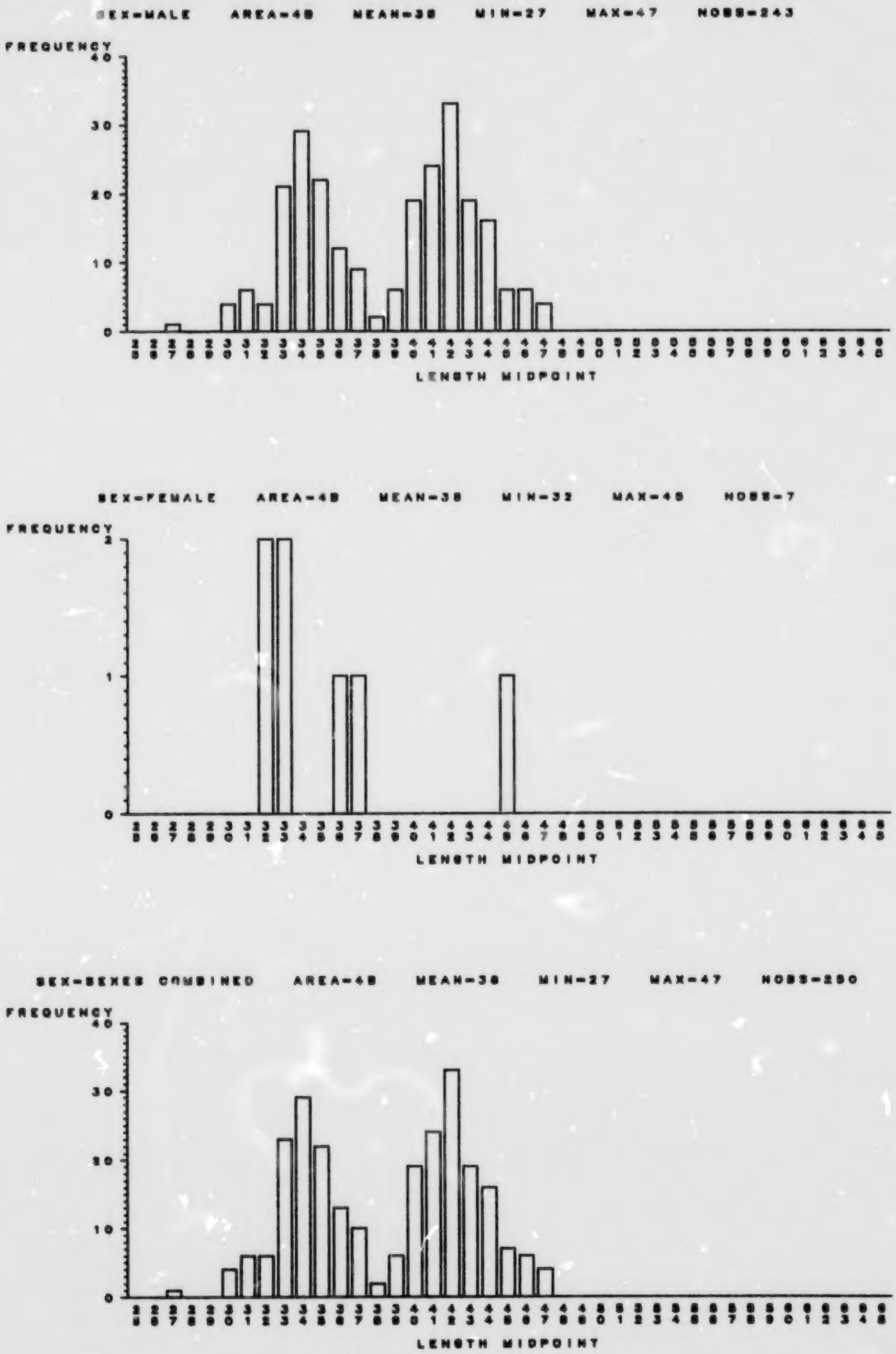


Fig. 8.4. Length frequencies for male, female and sexes combined port sampled pollock from Major area 4B for spring 1990.

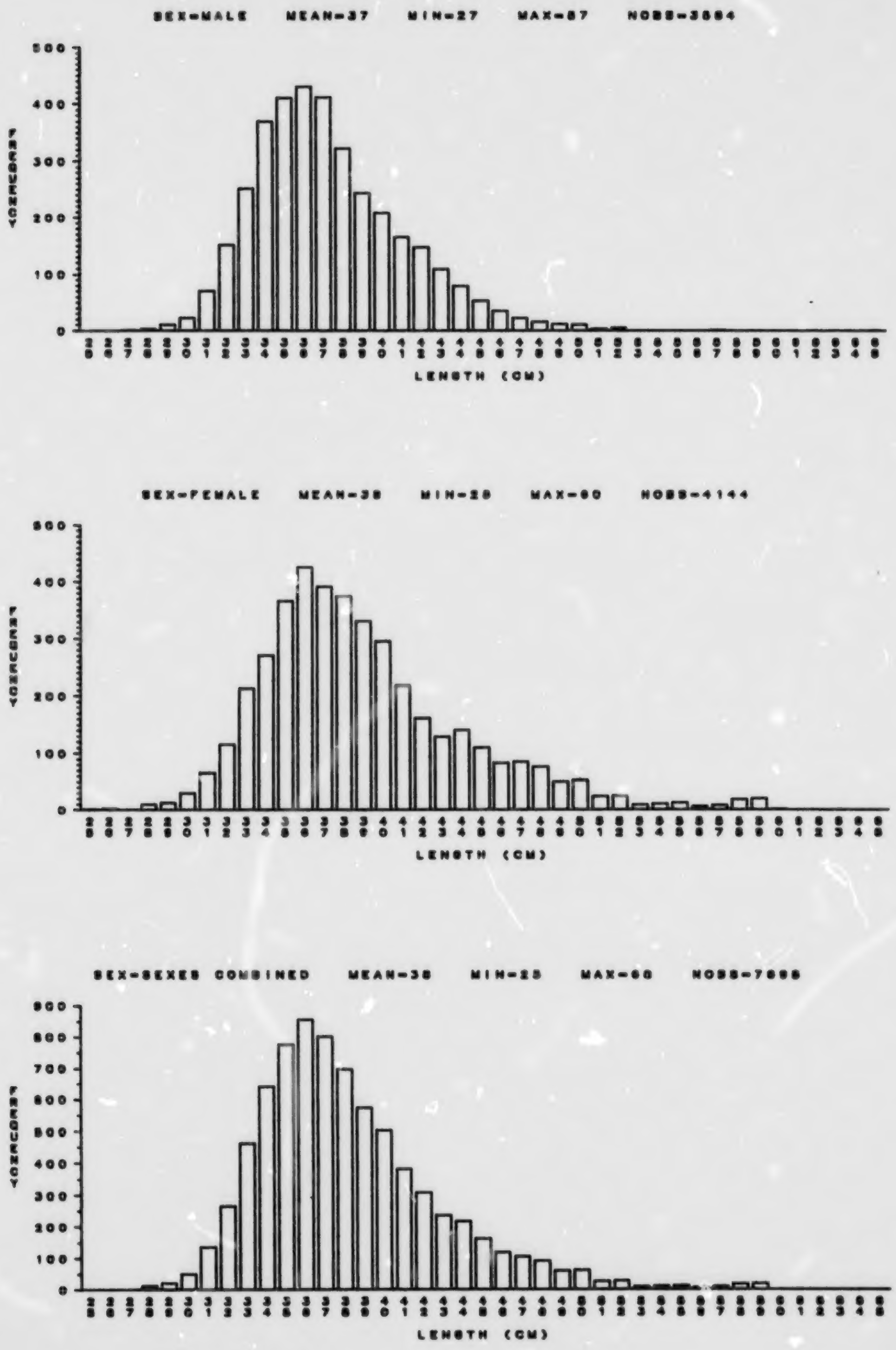


Fig. 8.5. von Bertalanffy length at age growth curves for pollock from the Strait of Georgia (Thompson, 1981).

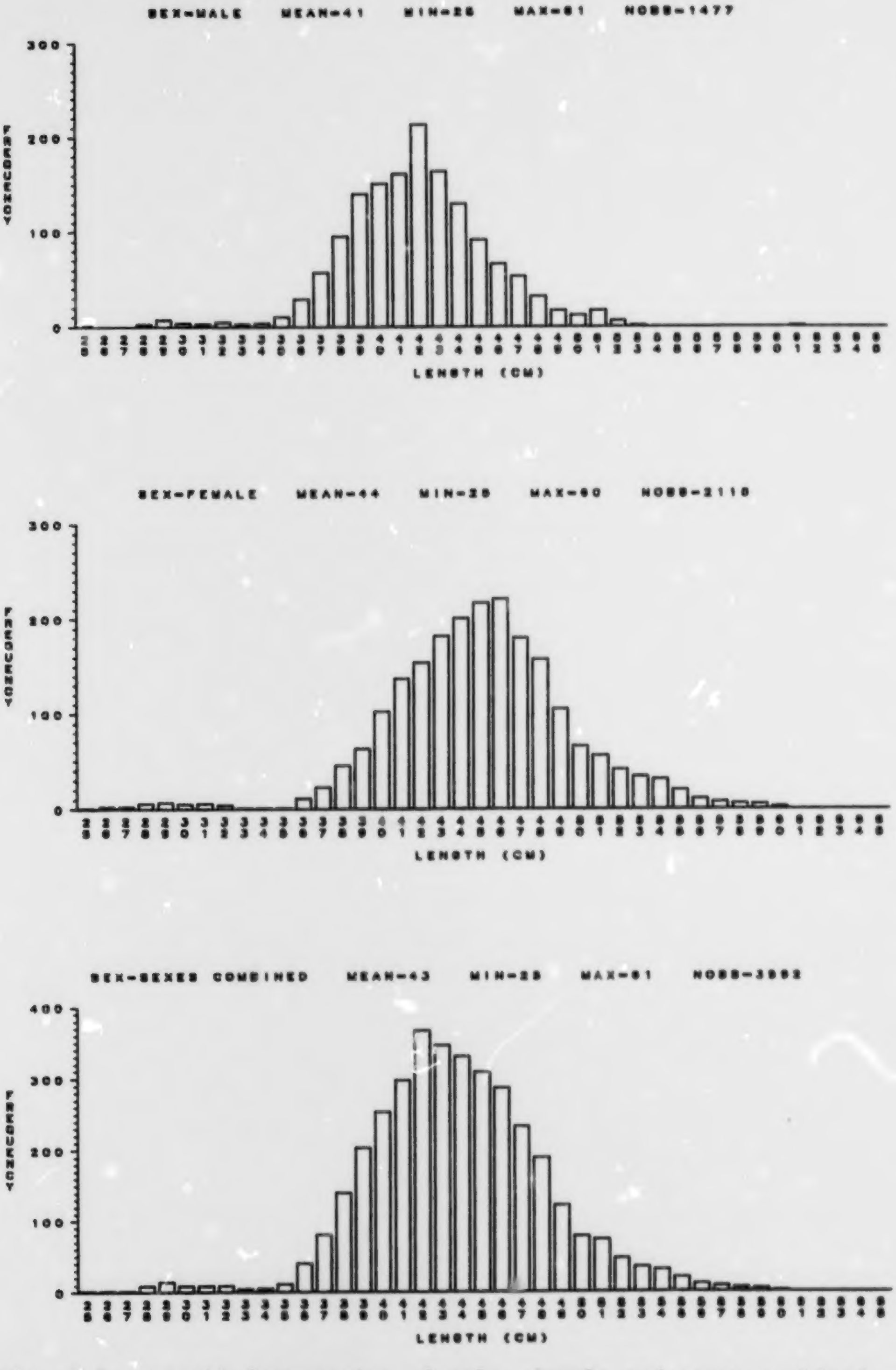


Fig. 8.6. Length frequencies of male, female and sexes combined pollock intercepted by the foreign, supplemental and joint venture hake fisheries off the West Coast of Vancouver Island (Major areas 3C and 3D), 1987.

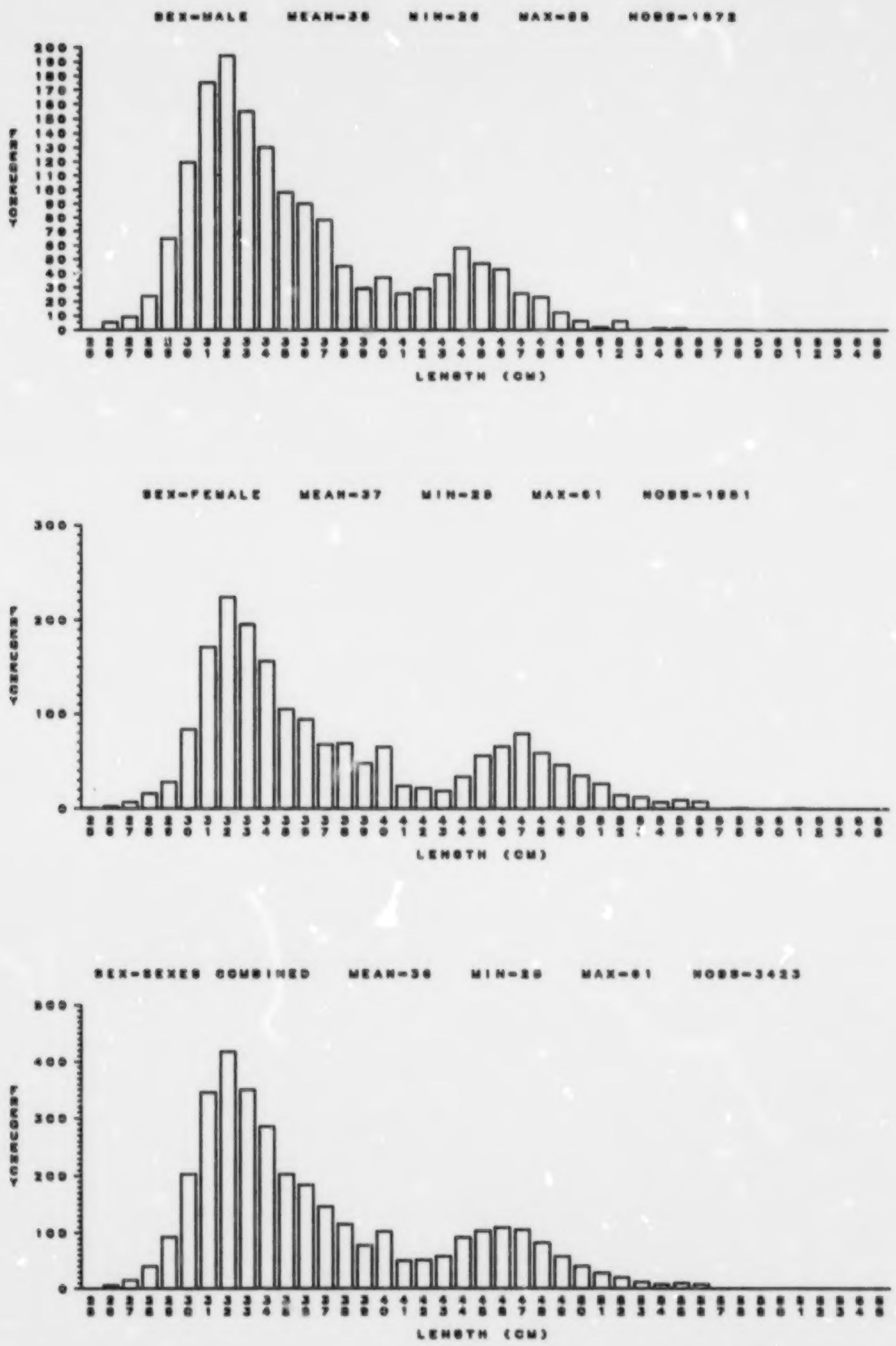


Fig. 8.7. Length frequencies of male, female and sexes combined pollock intercepted by the foreign, supplemental and joint venture hake fisheries off the west coast of Vancouver Island (Major areas 3C and 3D), 1988.

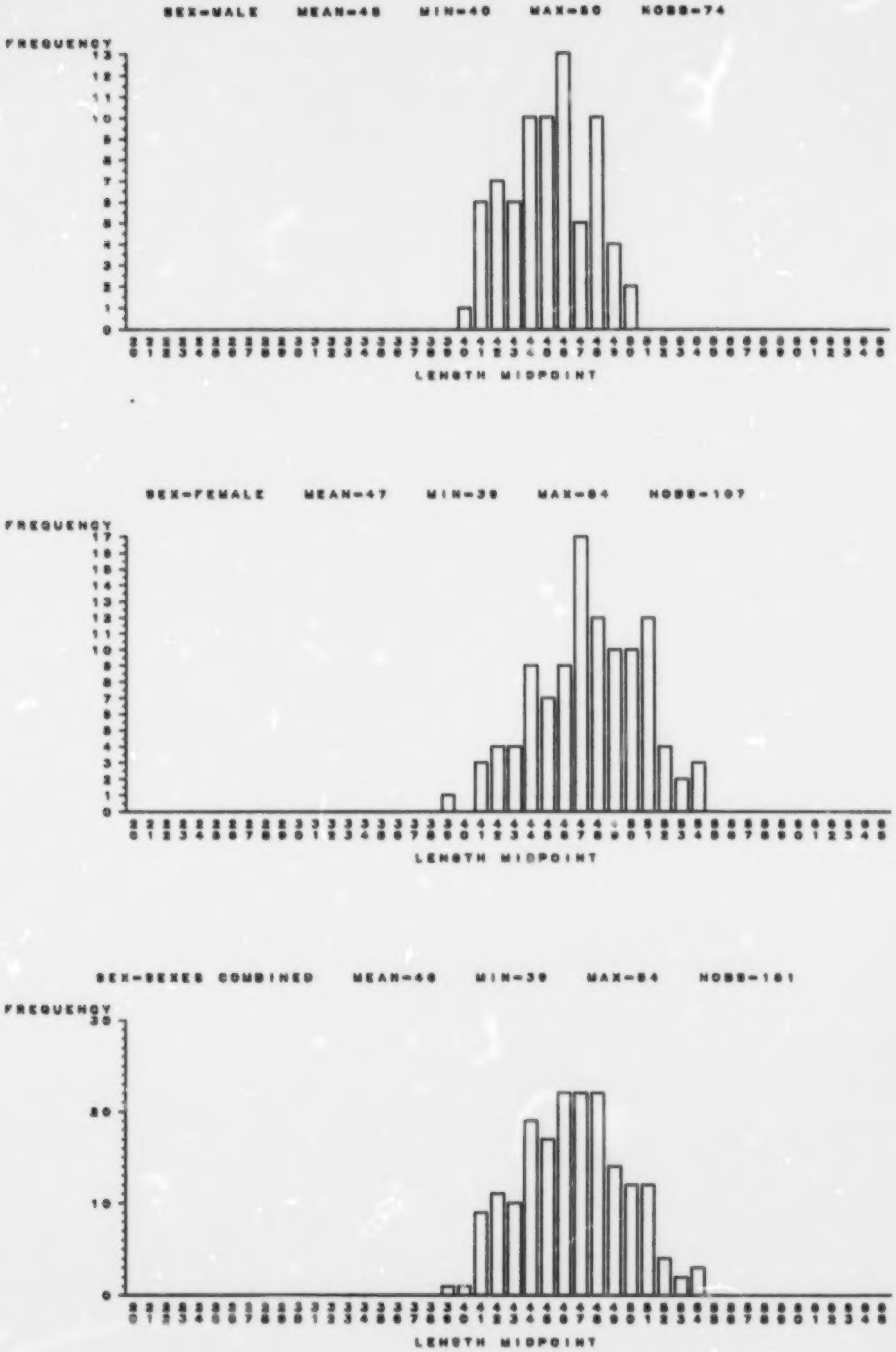


Fig. 8.8. Length frequencies of male, female and combined pollock intercepted by the foreign, supplemental and joint venture hake fisheries off the west coast of Vancouver Island (Major areas 3C and 3D), 1989.

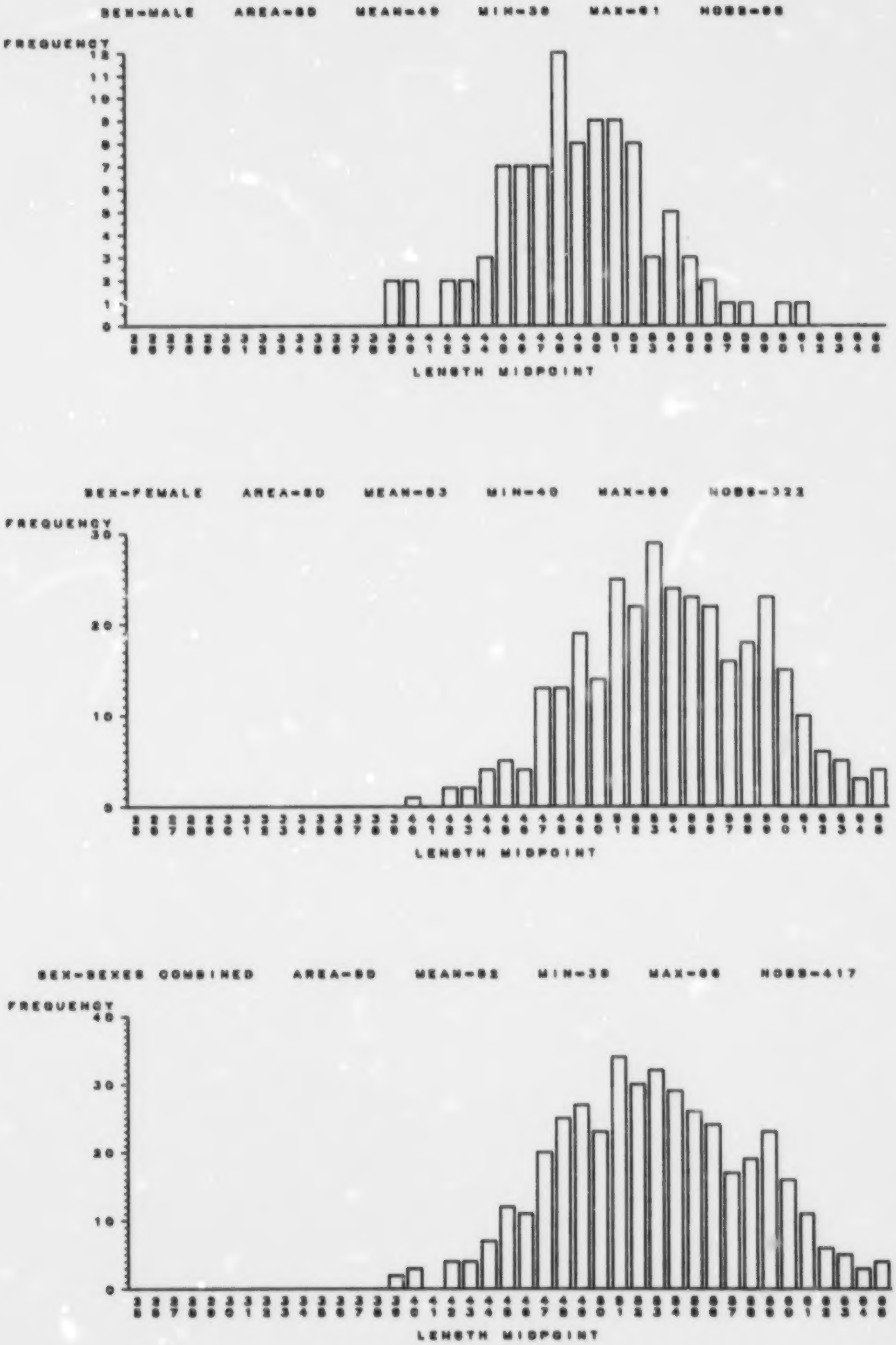


Fig. 8.9. von Bertalanffy length at age growth curves for pollock from Queen Charlotte Sound (Thompson, 1981).

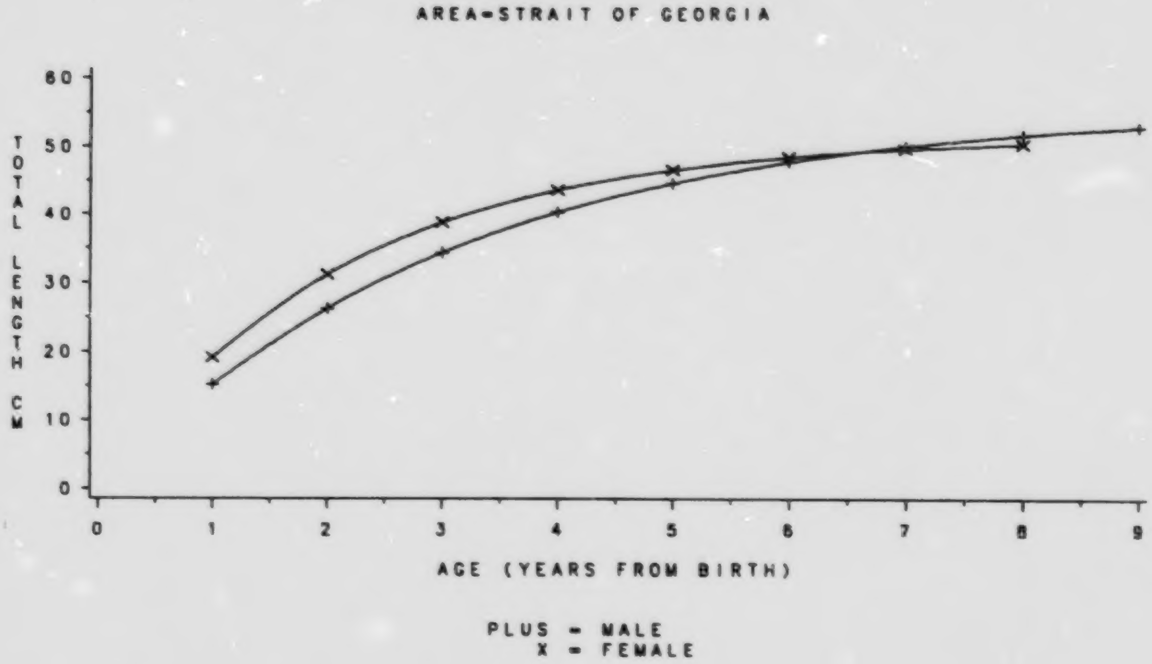


Fig. 8.10. Length frequencies of male, female and sexes combined pollock sampled aboard the M.V. Gail Bernice in Queen Charlotte Sound, 1989.

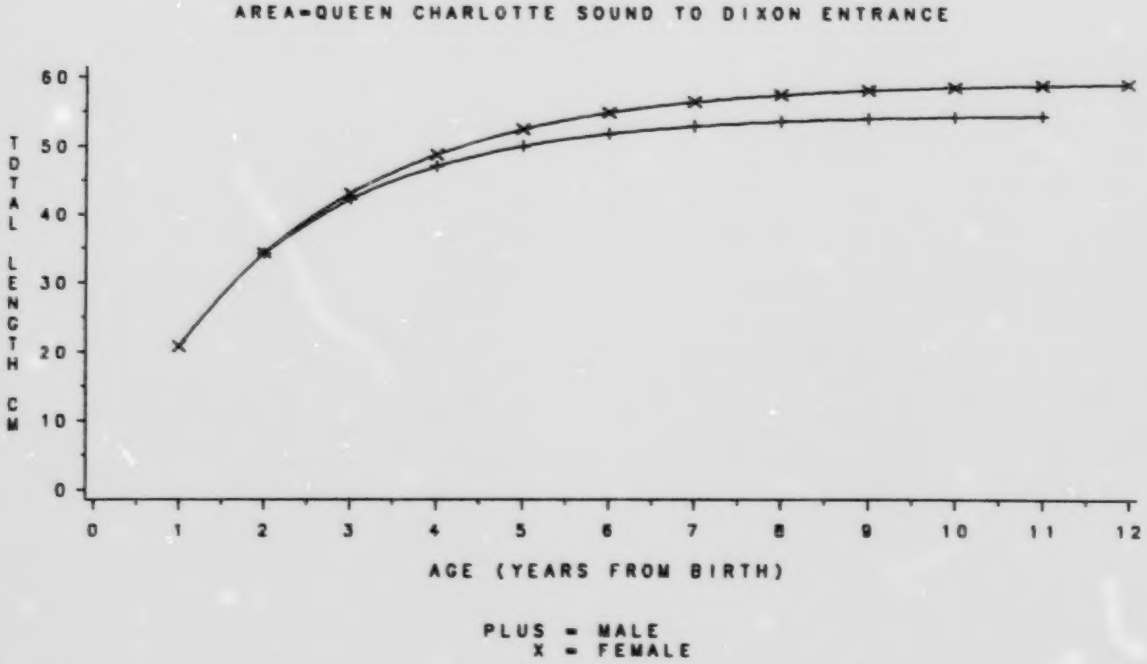


Fig. 8.11. Length frequencies of male, female and sexes combined for port sampled pollock from Major Area 5D, spring 1990.

9.0 SLOPE ROCKFISHES

by L. J. Richards

(Pacific ocean perch, redstripe rockfish, yellowmouth rockfish, and rougheye rockfish)

9.0.1 General Introduction

This is an interim year for slope rockfish stock assessments. No new analyses have been conducted and yield options (Table 9.1) remain unchanged from 1989 (Leaman 1990). Some modifications have been made to the format of this document, however. In particular, the layout of the tables has changed from previous assessments. Minor differences in catch statistics from those previously reported result from updated calls to the groundfish trawl data base maintained at the Pacific Biological Station. New statistical analyses for all major stocks are planned over the next two years.

Rockfish are the mainstay of the B.C. trawl fishery with a coastwide catch of 23 kt in 1989 (Fig. 9.1). The catch of slope rockfish (primarily Pacific ocean perch, rougheye rockfish, redstripe rockfish, and yellowmouth rockfish) increased steadily between 1979-1986 and has remained near the 1986 level. However, the relative importance of slope rockfish in the total catch has decreased in recent years, due to large catches of yellowtail, silvergray, and other shelf rockfish. Slope rockfish now account for approximately half of the rockfish trawl catch.

In 1986 and 1989, managers implemented coastwide trip limits in an attempt to reduce the complexity of the previous management plan. This measure was continued in 1990. In effect, individual area quotas were summed and percentages of the quota were assigned to each of the four quarters of the calendar year. In order to further protect Goose Island Gully stocks, this area remained closed to the retention of Pacific ocean perch until May 15, 1990. In addition, Pacific ocean perch in Area 3C were managed on a specific area basis, due to the small quota for that area.

9.0.2 Coastwide yellowmouth rockfish (Sebastes reedi)

Concerns were raised in 1990 regarding an apparent increased availability of yellowmouth rockfish. The following table summarizes yellowmouth rockfish catches between Jan. 1 and July 7 for 1987-90, as well as the total catch for the year and the coastwide quota.

Year	Catch	CPUE	Total Catch	Quota
87	1490.0	1.902	1737	1200
88	784.9	1.371	1186	1225
89	689.8	1.028	1387	1450
90	1063.5	0.820	-	1380

*Data to July 7

Although catches have increased in 1990 over the same period in 1988-89, CPUE has decreased. In fact, CPUE in 1990 is the lowest for the 1987-90 period, and half the value attained in 1987, a year with higher catches. There is no evidence for an increase in availability and stocks appear to be declining in abundance. A large overrun of the quota occurred in 1987. Continued overruns will deplete the stock, resulting in reduced estimates of sustainable yield in future assessments.

9.1.1 Southwest Vancouver Island Pacific ocean perch (Sebastes alutus) (Area 3C including Area 125)

9.1.1.1 Catch Statistics

Catch statistics for southwest Vancouver Island Pacific ocean perch are reported in Table 9.2. This table and the following tables differ in format from the corresponding tables in previous documents. Instead of listing logbook catch and effort (0% qualification in previous documents), the column labelled "0Pr" gives the proportion of the total catch for which there are corresponding logbooks. Similarly, the column labelled "25Pr" gives the proportion of the total catch meeting the 25% qualification criterion. The 25% qualified catch and effort are obtained from the sum of catch and effort over trips for which at least 25% of the catch is comprised of the species of interest. Values of CPUE are determined from the ratio of total logbook catch and effort (0CPUE) and from the ratio of 25% qualified catch and effort (25CPUE). Note that Table 9.2 also includes information for northwest Vancouver Island and for redstripe rockfish.

An overharvesting experiment was conducted on the Pacific ocean perch stock off southwest Vancouver Island, with a quota of 500 t between 1980 and 1984 (Leaman and Stanley 1990). Catches exceeded the quota during most of the experimental period (Fig. 9.2). In 1987, the quota was returned to the sustainable level of 150 t. Catches have continued to exceed the quota, however, in spite of attempts to limit the harvest to an incidental fishery. In 1989 and 1990, the stock was managed by a 4.5 t trip limit between January 1 and March 31 and a 2.0 t trip limit from April 1. As approximately 50% of the 1989 and 1990 catch met the 25% qualification level, it is apparent that some directed fishing still occurs on this stock.

Values of 25% qualified CPUE were highly variable for this fishery during the period of low catches in the 1970s. Peak values occurred in 1978 and 1979, prior to the overfishing experiment. Since 1979, there has been a declining trend in CPUE. The lowest CPUE value occurred in 1985, followed by two years of relatively high CPUE. However, values of CPUE during 1988-90 have returned to low levels and are now similar to the 1985 value.

9.1.1.2 Yield Options

The poor condition of the Pacific ocean perch stock is well documented by Leaman and Stanley (1990). In addition, values of 25% qualified CPUE in 1988-89 are less than a third of the comparable values for northwest Vancouver Island, and the preliminary value for 1990 is also low. Sustainable yield (Table 9.1) is estimated to range from 70-200 t (Leaman 1988). Rehabilitation of this stock will require at least a decade, even with low fishing mortality.

9.1.2. Southwest Vancouver Island redstripe rockfish (Sebastes proriger)

9.1.2.1 Catch Statistics

Historical catches of redstripe rockfish off southwest Vancouver Island have been small (Table 9.2). However, the catch jumped to 515 t in 1986 from its previous high of 61 t in 1985, coincident with coastwide management. At that time, the rapid catch of quota rockfish forced the domestic fleet to find other red rockfish to satisfy market demands. Although smaller than Pacific ocean perch in most areas, redstripe rockfish do attain marketable size (>30 cm) off southwest Vancouver Island. Catches have declined since 1986 to 290 t in 1989. The 1989 value of 25% qualified CPUE is considerably lower than values recorded during the 1986-88 period. No management has ever been applied to this stock.

9.1.2.2 Yield Options

No quantitative conclusions concerning the condition of this stock are possible at present. Sustainable yield (Table 9.1) is estimated to range from 200-1000 t (Leaman 1988). Yield should be maintained at levels less than 500 t for another few years so that the sustainable level can be evaluated.

9.2.1 Northwest Vancouver Island Pacific ocean perch (Sebastes alutus) (Area 3D excluding area 125)

9.2.1.1 Catch Statistics

Directed fishing for Pacific ocean perch off the northwest coast of Vancouver Island began in 1983 (Table 9.2, Fig. 9.2). Catches have been particularly high in years with coastwide management (1986, 1989-90). This is because there are no timing restrictions for fishing on this stock and it is located close to Vancouver. The 1989 catch was more than twice the quota of 400 t. Although values of 25% qualified CPUE are considerably higher than for southwest Vancouver Island, declines have occurred in 1989 and 1990.

9.2.1.2 Yield Options

There is little information upon which to base an assessment. In spite of the large catches in 1986, no biological samples were obtained, primarily because of the landings at U.S. ports. The intense Pacific ocean perch fisheries of the mid-1960s found no significant quantities of fish in this area. Sustainable yield is estimated to range from 200-600 t. The high catches during periods of coastwide management (1986, 1989-90) could lead to lower estimates of sustainable yield in future assessments.

9.3.1 Northwest Vancouver Island/Queen Charlotte Sound redstripe rockfish (Sebastes proriger)

9.3.1.1 Catch Statistics

The northwest Vancouver Island/Queen Charlotte region includes Area 3D (excluding area 125), as well as Goose Island and Mitchell's Gullies (Area 5A/B). Catches of redstripe rockfish in this region by foreign trawlers may have been substantial (Leaman et al. 1978). Domestic catches were low until 1986 when over 1000 t were landed (Table 9.3) coincident with coastwide quotas. Values of 25% qualified CPUE are low for a new fishery and have declined between 1987-89. No management has ever been applied to this stock.

9.3.1.2 Yield Options

No quantitative conclusions concerning the condition of this stock are possible at present, as limited catch statistics provide the only available information. The sustainable yield (Table 9.1) is estimated to range from 350-900 t (Leaman 1988).

9.3.2 Northwest Vancouver Island/Queen Charlotte Sound yellowmouth rockfish (Sebastes reedi)

9.3.2.1 Catch Statistics

Historical catches of yellowmouth rockfish in the northwest Vancouver Island/Queen Charlotte Sound region are uncertain due to problems with species designation (Leaman et al. 1978). Record catches by the domestic fishery (Table 9.3) occurred in 1986-87, coincident with coastwide quotas. At the same time, values of 25% qualified CPUE were high, with the fishery concentrating on aggregations of spawning females. Since 1987, values of 25% qualified CPUE have declined.

9.3.2.2 Yield Options

No analytic assessments of this stock have been conducted due to a paucity of useful data. Sustainable yield (Table 9.1) is estimated to range from 250-750 t (Leaman 1988).

9.3.3 Queen Charlotte Sound Pacific ocean perch (Sebastes alutus)

9.3.3.1 Catch Statistics

The format of catch statistics (Table 9.4) for Pacific ocean perch in Queen Charlotte Sound remains unchanged from the 1989 assessment (Leaman 1990). Values of CPUE for this area are standardized following Ketchen (1981), to account for changes in fishing power of vessels over the time series. Since 1985, the annual Pacific ocean perch fishery in this area has been closed until April 1. After April 1, the fishing effort in Goose Island Gully has been substantial (>1000 h), with relatively stable values of standardized CPUE (Fig. 9.3). Recent catch statistics for Mitchell's Gully are of limited value due to the low catch and effort there.

9.3.3.2 Condition of the Stock

Goose Island Gully Pacific ocean perch stocks have been analyzed more intensively than any groundfish stock on the Pacific coast and these analyses were reviewed in Leaman (1988). All of the studies concluded that the Pacific ocean perch stocks are severely depleted. Furthermore, increased yields could be obtained if stocks were rehabilitated to higher biomass levels. Quota management for these stocks has been imprecise and quota overruns have occurred consistently since 1983. The stocks have probably continued to decline since management began in 1977.

9.3.3.3 Yield Options

The rebuilding timetable at various levels of fishing mortality was outlined by Archibald et al. (1983). With the exception of complete closure, there are relatively small differences in the periods of rehabilitation between fishing mortality rates of F=0.03-0.05 (Archibald et al. 1983, Leaman and Stanley 1985). Present stock biomass is estimated to be in the range of 8-13 kt, based on simulations using the 1985 and 1977 age compositions, respectively. Yield estimates (Table 9.1) of 700-1000 t (including Mitchell's Gully) are derived from F=0.06. Stock rehabilitation is not expected at this level of F.

9.4.1 Moresby Gully Pacific Ocean Perch (Sebastes alutus)

9.4.1.1 Catch Statistics

The Moresby Gully Pacific ocean perch stock was discovered by DFO in 1973. Prior to 1980, commercial catches were low and 25% qualified CPUE was variable (Table 9.5, Fig. 9.3). Beginning in 1980, the trawl fleet began to target on this stock. Values of 25% qualified CPUE increased between 1979-83 and then began to decline. The declining trend in 25% qualified CPUE has continued through 1990. The 1988 catch of 3104 t exceeded the 3000-t quota, but with coastwide management in 1989, the catch of 1507 t was only half of the quota. The quota was reduced to 2450 t for 1990.

9.4.1.2 Condition of the Stock

The declining trend in 25% qualified CPUE suggests that the fishery is having a negative effect on the stock. Quantifying this effect is difficult, however, due to the short history of the fishery. Although the strong 1976 cohort is now almost fully recruited to the fishery, it does not appear to be buffering the decline in CPUE.

There has been a steady shift toward smaller fish in the catch since 1981 (Leaman 1988). If CPUE indexes abundance, then the biomass of larger fish has decreased substantially. Length frequency samples from 1989 are bimodal, largely as a result of the recruiting 1976 cohort (Leaman 1990).

9.4.1.3 Yield Options

In 1987, an internal Groundfish Section review estimated that considerably greater yield (3500 t) than was previously identified (2000 t) could be taken from this stock. Since that time, values of 25% qualified CPUE have continued to decline and caution is warranted. The high-risk yield (3000 t) is based on the alternative 1987 review. The low-risk sustainable yield is estimated to be 1900 t (Table 9.1).

9.4.2 Moresby Gully redstripe rockfish (Sebastes proriger)

9.4.2.1 Catch Statistics

Redstripe rockfish have experienced relatively minor catches in Moresby Gully (Table 9.3). The largest catch to date was 307 t, occurring in 1987. Values of 25% qualified CPUE have been low (≤0.7 t/h) and variable. No management has ever been applied to this stock.

9.4.2.2 Yield Options

The historical catches can probably be sustained. Indeed, the large Pacific ocean perch stock in this area may be indicative of a relatively large redstripe rockfish stock, based on analysis of historical patterns of association between these species (Leaman and Nagtegaal 1987). The catch proportion ratio from that analysis (0.217) implied a sustainable yield range of 350-570 t for redstripe rockfish in Moresby Gully (Table 9.1).

9.4.3 Moresby Gully yellowmouth rockfish (Sebastes reedi)

9.4.3.1 Catch Statistics

Catch and 25% qualified CPUE have been variable for the Moresby Gully yellowmouth rockfish fishery (Table 9.3). The highest catch of 442 t occurred in 1982 and the 1989 catch was 175 t. Fleet activity is generally directed at Pacific ocean perch in this area. The proportion of the catch meeting the 25% qualification criteria has been less than 50% for most years.

9.4.3.2 Yield Options

There is little information with which to assess this stock. Based on historical catch, sustainable yields (Table 9.1) are estimated to range from 160-500 t (Leaman 1988).

9.5.1 West Queen Charlotte Islands (Area 5E(S)) Pacific Ocean Perch (Sebastes alutus)

9.5.1.1 Catch Statistics

The largest recorded catch (2414 t) of Pacific ocean perch in the West Queen Charlotte Islands occurred in 1978 (Table 9.6, Fig. 9.4). A 600-t quota was placed on the stock in 1979, and catches dropped. However, catches have substantially exceeded the quota in most years. The high catches between 1983-86 coincided with management on the basis of a slope rockfish assemblage with seasonal openings. In 1989, the quota was further reduced to 400 t. Values of 25% qualified CPUE were relatively high during the 1977-84 period, and since 1984, have been stable at a lower level. The preliminary 1990 catch already exceeds the 400-t quota, and the corresponding value of 25% qualified CPUE is the lowest recorded.

9.5.1.2 Yield Options

The low level of 25% qualified CPUE since 1984 and the high mortality rate estimated by size frequency analyses (Leaman

1990) suggest declining stock abundance. Sustainable yield (Table 9.1) is estimated to range from 300-500 t.

9.5.2. West Coast Queen Charlotte Islands (Area 5E(S)) Redstripe Rockfish (Sebastes proriger)

9.5.2.1 Catch Statistics

Catches of redstripe rockfish off the west coast of the Queen Charlotte Islands were low until 1985 when the catch was 918 t (Table 9.7, Fig. 9.5). Catch decreased between 1985-89, and the 1989 catch is comparable to the 1977-84 period. Values of 25% qualified CPUE were variable during the early part of the fishery. Since 1984, 25% qualified CPUE has tended to decline, although the preliminary 1990 value is high. No management has ever been applied to this stock.

9.5.2.2 Yield Options

Cluster analyses of catches from this area (Leaman and Nagtegaal 1987) suggest that the typical catch ratio of Pacific ocean perch to redstripe rockfish is 0.217. Based on the yield options identified for Pacific ocean perch (Table 9.1), the sustainable yield for redstripe rockfish is estimated to range from 60-100 t. These figures may be conservative if the landed catch does not accurately reflect the true catch of redstripe rockfish. There has been no evidence of such market limitations in recent years, although discards may have occurred in the late 1970s.

9.5.3 West Coast Queen Charlotte Islands (Area 5E(S)) Yellowmouth Rockfish (Sebastes reedi)

9.5.3.1 Catch Statistics

Catches of yellowmouth rockfish off the west coast of the Queen Charlotte Islands peaked in 1977 at 1257 t (Table 9.7, Fig 9.5). A 750-t quota was placed on the stock in 1979. The quota was modified to 800 t in 1980 and to 600 t in 1982. Values of 25% qualified CPUE have been somewhat variable over the history of the fishery, but exhibit a general declining trend. The preliminary 1990 value of 25% qualified CPUE is the lowest recorded.

9.5.3.2 Yield Options

No analytical assessments of this stock have been conducted and few biological samples have been collected. Sustainable yield (Table 9.1) is estimated to range from 400-700 t.

9.5.4 West Coast Queen Charlotte Islands (Area 5E(S)) Rougheye Rockfish (*Sebastes aleutianus*)

9.5.4.1 Catch Statistics

Catches of rougheye rockfish off the west coast of the Queen Charlotte Islands have historically been low, with the maximum recorded catch of 353 t occurring in 1988 (Table 9.7). The corresponding values of 25% qualified CPUE were also low during 1985-88. The 1989 value of 25% qualified CPUE is similar to higher values obtained during 1983-84.

9.5.4.2 Yield Options

Sustainable yield (Table 9.1) is estimated to range from 200-300 t.

9.6.1 West Queen Charlotte Islands (Area 5E(N)) Rockfish (all *Sebastes*)

9.6.1.1 Introduction

The Langara Spit area (north of 54°) has been the object of an experimental open-fishing program since the fall of 1983. Leaman and Stanley (1990) review this experiment and describe the stock declines that have occurred to date. An update of the catch statistics for the main stocks is presented below.

9.6.1.2 Catch Statistics

Annual catches of Pacific ocean perch (Table 9.6, Fig. 9.4), redstripe rockfish, yellowmouth rockfish, and rougheye rockfish (Table 9.7) increased following the inception of the experiment in 1983. Peak catches occurred in 1986 for Pacific ocean perch, redstripe rockfish and yellowmouth rockfish. However, redstripe rockfish and yellowmouth rockfish were recorded by observers in catches by Japanese trawlers during 1977 (Leaman et al. 1978). Hence, the exact exploitation history for these species is uncertain. The largest rougheye rockfish catch (516 t) was recorded in 1989.

Values of 25% qualified CPUE have declined for all species over the course of the experiment. By 1988, values were considerably below peak values. The higher values of 25% qualified CPUE for Pacific ocean perch in 1989-90, relative to 1988, are believed to reflect misreporting of catches from more productive areas.

The species composition of the catch has been variable (Table 9.8, Fig. 9.6). Although Pacific ocean perch has always been the major species, other species (with lower values of CPUE) have alternated in relative importance.

9.6.1.3 Condition of the stock

The Langara Spit rockfish stocks continue to be in poor condition, as described by Leaman and Stanley (1990). CPUE has decreased since the initiation of the experimental fishery and the biological characteristics of Pacific ocean perch indicate further stock depletion (Leaman 1990). At the beginning of the experiment, the fishery was based primarily on fish less than 10 yr of age. These fish were not fully recruited to the fishery and had been sexually mature for only 1-2 yr. Age samples from 1989 indicate that the 1985-88 fishery was based almost entirely on the 1976 cohort. The 1976 cohort included over 60% of the number of fish in the 1985 catch. By 1989, however, the 1976 cohort included only 30% of the number of fish in the catch, due to high fishing mortality (near 0.5). The 1980 cohort, not particularly strong in other stocks, is now similar in abundance to the 1976 cohort in the Langara Spit area. The 1976 cohort continues to be a dominant feature of the less exploited Moresby Gully stock.

9.6.1.4 Yield Options

Catches of Pacific ocean perch in the order of 2000 t/yr appear to have led to total mortality rates (Z) between 0.5-0.7. If the estimates of Z are correct, then sustainable yields (Table 9.1) with Z=0.10 are estimated to range from 150-170 t for Pacific ocean perch and from 50-100 t for rougheye rockfish. Sustainable yields range from 500-700 t for redstripe rockfish and from 350-500 t for yellowmouth rockfish. Higher yields from this area could be realized through rehabilitation, although a return to maximum long-term yield could take 30-40 y, even with rigorous conservation.

The open-fishing component of this experiment was originally proposed to terminate at the end of 1987 and be followed by a stock rebuilding phase, with little or no fishing mortality. The results of the second phase would be used to provide guidance on management policies for these and other rockfish stocks. Managers continued the open-fishing portion of the experiment during 1988-90, to provide further evidence of the negative effects of unrestricted fishing. Declines in stock biomass have now been well documented (Leaman and Stanley 1990). Only minor scientific benefits can be expected from continued open fishing.

Table 9.1. Yield options for slope rockfishes off the British Columbia coast for 1991.

Species	Area	Yield Options (t)		
		Low risk	-	High risk
Pacific ocean perch	3C	100	-	200
Redstripe rockfish	3C	200	-	1000
Pacific ocean perch	3D	200	-	600
Yellowmouth rockfish	3D/5A	250	-	750
Redstripe rockfish	3D/5A	350	-	900
Pacific ocean perch	5A/B	700	-	1000
Pacific ocean perch	Moresby	1900	-	3000
Yellowmouth rockfish	Moresby	160	-	500
Redstripe rockfish	Moresby	350	-	570
Pacific ocean perch	5E(S)	300	-	500
Yellowmouth rockfish	5E(S)	400	-	700
Rougheye rockfish	5E(S)	200	-	300
Redstripe rockfish	5E(S)	50	-	100
Slope rockfish (Pacific ocean perch, yellowmouth and rougheye)				
Jan.-June	5E(S)	300	-	500
Sep.-Dec.	5E(S)	600	-	1000
Pacific ocean perch	5E(N)	150	-	170
Yellowmouth rockfish	5E(N)	350	-	500
Rougheye rockfish	5E(N)	50	-	100
Redstripe rockfish	5E(N)	500	-	700
Slope rockfish (Pacific ocean perch and rougheye)				
	5E(N)	200	-	270

Table 9.2. Canadian trawl catch (t), the proportion of the trawl catch with corresponding logbooks (0Pr), the nominal CPUE (0CPUE, t/h), the proportion of the trawl catch meeting the 25% qualification criterion (25Pr), and the 25% qualified CPUE (25CPUE, t/h) for Pacific ocean perch and redstripe rockfish off southwest Vancouver Island (areas 121-125) and Pacific ocean perch off northwest Vancouver Island (areas 126-127). Data for 1990 are given to July 16.

Year	Southwest Vancouver Island					Northwest Vancouver Island				
	Catch	0Pr	0CPUE	25Pr	25CPUE	Catch	0Pr	0CPUE	25Pr	25CPUE
					Pacific ocean perch					
67	7.0	1.000	0.426	0.973	0.471	0.0	-	-	-	-
68	0.1	1.000	0.018	-	-	0.4	1.000	0.005	-	-
69	2.5	1.000	0.062	0.506	0.101	0.0	-	-	-	-
70	303.9	0.993	0.521	0.899	0.932	0.4	1.000	0.023	-	-
71	218.4	0.973	0.335	0.920	0.501	0.0	-	-	-	-
72	117.3	0.113	0.624	0.108	0.889	0.0	-	-	-	-
73	0.0	-	-	-	-	0.0	-	-	-	-
74	0.0	-	-	-	-	2.9	1.000	0.050	-	-
75	5.5	1.000	0.033	0.267	0.208	0.0	-	-	-	-
76	1.3	1.000	0.257	0.675	0.869	0.0	-	-	-	-
77	16.2	0.924	0.033	0.545	0.190	0.0	-	-	-	-
78	53.1	0.994	0.693	0.960	1.310	2.9	0.106	0.612	-	-
79	124.9	0.994	0.618	0.969	1.413	0.0	-	-	-	-
80	429.8	0.996	0.572	0.920	1.038	0.0	-	-	-	-
81	547.3	0.970	0.488	0.923	0.711	0.2	1.000	0.011	-	-
82	508.0	0.953	0.530	0.891	0.815	0.1	1.000	0.004	-	-
83	751.5	0.474	0.419	0.433	0.791	85.8	0.441	0.513	0.292	1.823
84	551.2	0.738	0.505	0.733	0.561	192.8	0.759	1.247	0.749	1.256
85	243.1	0.917	0.206	0.806	0.283	312.7	0.840	0.518	0.696	0.610
86	242.1	0.737	0.326	0.580	0.759	1046.0	0.629	0.808	0.584	1.043
87	542.3	0.838	0.455	0.728	0.857	450.5	0.921	0.633	0.806	1.192
88	307.5	0.678	0.115	0.253	0.339	491.9	0.945	0.685	0.845	1.251
89	279.2	0.988	0.106	0.526	0.333	993.9	0.996	0.802	0.936	0.974
90	243.8	0.822	0.109	0.469	0.286	640.7	0.788	0.678	0.750	0.857
					Redstripe Rockfish					
77	0.3	1.000	0.007	0.098	0.032					
78	0.6	1.000	0.067	0.622	0.376					
79	2.0	1.000	0.228	-	-					
80	0.3	1.000	0.291	-	-					
81	12.8	1.000	1.216	0.732	2.198					
82	2.5	1.000	0.050	0.955	1.383					
83	30.1	0.819	0.084	0.388	0.373					
84	34.6	0.319	0.033	0.107	1.173					
85	61.0	0.724	0.109	0.317	0.435					
86	514.7	0.715	0.220	0.469	0.842					
87	377.1	0.863	0.250	0.530	0.877					
88	392.9	0.951	0.231	0.598	0.739					
89	289.5	0.990	0.143	0.693	0.473					
90	205.9	0.866	0.162	0.579	0.579					

Table 9.3. Canadian trawl catch (t), the proportion of the trawl catch with corresponding logbooks (OPr), the nominal CPUE (OCPUE, t/h), the proportion of the trawl catch meeting the 25% qualification criterion (25Pr), and the 25% qualified CPUE (25CPUE, t/h) for redstripe and yellowmouth rockfish for northwest Vancouver Island, Queen Charlotte Sound (including Goose Island and Mitchell's Gully) and Moresby Gully. Data for 1990 are given to July 16.

Year	North Van. Is.- Queen Charl. Sound					Moresby Gully				
	Catch	OPr	OCPUE	25Pr	25CPUE	Catch	OPr	OCPUE	25Pr	25CPUE
					Redstripe Rockfish					
75	12.9	1.000	0.375	1.000	0.375	0.0	-	-	-	-
76	11.6	1.000	0.253	0.664	1.102	0.0	-	-	-	-
77	33.5	1.000	0.094	0.510	0.286	0.9	1.000	0.038	-	-
78	24.9	1.000	0.059	0.341	0.239	3.8	1.000	0.078	0.212	0.203
79	8.3	1.000	0.055	0.621	0.709	1.5	1.000	0.054	-	-
80	0.0	-	-	-	-	19.3	1.000	0.100	0.065	0.194
81	0.0	-	-	-	-	5.3	0.740	0.034	-	-
82	2.6	1.000	0.021	-	-	22.8	0.774	0.062	0.093	0.386
83	40.8	0.938	0.272	0.899	16.282	19.9	0.788	0.146	0.311	0.247
84	49.4	0.317	0.041	0.041	0.366	70.5	0.469	0.075	0.263	0.263
85	159.9	0.707	0.113	0.399	0.284	180.8	0.845	0.281	0.535	0.683
86	1073.2	0.918	0.484	0.749	1.115	109.6	0.976	0.200	0.468	0.398
87	1344.8	0.915	0.574	0.741	1.199	306.7	0.944	0.362	0.575	0.717
88	601.4	0.976	0.296	0.718	0.783	199.3	0.982	0.156	0.392	0.408
89	788.4	0.995	0.308	0.733	0.699	233.6	1.000	0.258	0.531	0.520
90	738.1	0.810	0.295	0.548	0.813	276.4	0.832	0.422	0.640	0.728
					Yellowmouth Rockfish					
71	5.3	1.000	0.170	-	-	0.0	-	-	-	-
72	0.0	-	-	-	-	0.0	-	-	-	-
73	176.6	1.000	4.774	0.998	5.422	0.0	-	-	-	-
74	78.9	1.000	3.431	1.000	3.431	0.0	-	-	-	-
75	1.1	1.000	0.031	-	-	0.0	-	-	-	-
76	12.3	1.000	1.229	1.000	1.229	0.0	-	-	-	-
77	335.9	1.000	0.653	0.986	1.207	3.7	1.000	1.500	1.000	1.500
78	16.5	1.000	0.150	0.656	0.679	91.9	1.000	1.693	0.921	1.873
79	10.3	1.000	0.101	0.633	0.669	20.5	1.000	0.545	-	-
80	27.9	1.000	0.286	0.887	0.758	20.1	1.000	0.702	0.074	0.272
81	4.7	1.000	0.185	0.014	0.033	109.7	0.373	0.351	-	-
82	227.9	0.776	1.056	0.717	4.111	442.3	0.737	0.457	0.520	1.126
83	628.1	0.733	0.918	0.585	2.424	203.6	0.392	0.214	0.082	0.375
84	458.3	0.440	0.498	0.398	0.849	338.1	0.314	0.344	0.103	0.692
85	716.4	0.471	0.395	0.408	1.429	232.0	0.765	0.518	0.492	1.331
86	1208.4	0.782	0.738	0.676	1.414	100.3	1.000	0.411	0.643	0.720
87	1170.1	0.919	0.822	0.775	2.175	116.5	0.642	0.163	0.296	0.611
88	573.9	0.994	0.303	0.751	1.310	322.6	0.991	0.342	0.508	1.527
89	983.6	0.997	0.407	0.742	0.918	174.8	1.000	0.235	0.337	0.875
90	677.2	0.848	0.309	0.531	0.862	108.0	0.682	0.192	0.192	0.935

Table 9.4. Catch (t) (foreign and domestic) of Pacific ocean perch, standardized CPUE (t/h) and calculated total effort (h) on principal fishing grounds of Queen Charlotte Sound. (Fishery changed to a winter fishery on spawning females 1983-1985.) Data for 1990 are to July 1.

Year	Goose Island Gully			Mitchell's Gully		
	Catch	CPUE	Effort	Catch	CPUE	Effort
59	1890	.836	2261	-	-	-
60	1679	.698	2405	-	-	-
61	1199	.797	1504	-	-	-
62	1838	1.161	1583	-	-	-
63	3712	1.457	2548	-	-	-
64	3450	1.134	3042	57	-	-
65	7478	1.491	5015	488	.780	626
66	20752	1.441	14401	1369	.815	1680
67	12119	1.068	11347	5319	1.157	4597
68	10213	1.045	9773	2556	1.137	2248
69	6872	.763	9007	2945	.995	2960
70	6489	.672	9657	1296	1.010	1283
71	3455	.526	6568	813	.954	852
72	5645	.829	6809	995	.854	1165
73	3755	.773	4858	2264	1.351	1676
74	7269	.773	9404	1917	.974	1968
75	4209	.507	8302	1151	.989	1164
76	2442	.733	3332	576	.673	856
77	1693	.660	2565	256	.551	465
78	865	.821	1054	375	.817	459
79	951	.799	1190	480	.670	716
80	1226	.932	1316	305	.862	354
81	801	.760	1054	680	4.474	152
82	570	.514	1110	286	2.648	108
83	1215	1.257	967	31	.929	33
84	841	2.017	417	19	.594	32
85	743	.475	1565	80	.149	537
86	623	.534	1167	-	-	-
87	1548	.518	2989	98	.506	193
88	978	.572	1710	208	.507	411
89	954	.453	2104	224	.372	602
90	442	.449	983	62	.239	260

Table 9.5. Canadian trawl catch (t) of Pacific ocean perch, the proportion of the trawl catch with corresponding logbooks (OPr), the nominal CPUE (OCPUE, t/h), the proportion of the trawl catch meeting the 25% qualification criterion (25Pr), the 25% qualified CPUE (25CPUE, t/h), and the number of records meeting the 25% qualification criterion for Moresby Gully. Data for 1990 are given to July 16.

Year	Moresby Gully					
	Catch	OPr	OCPUE	25Pr	25CPUE	Records
68	1.1	1.000	0.324	1.000	0.324	1
69	0.8	1.000	0.033	-	-	0
70	27.3	0.936	0.043	0.137	0.278	3
71	9.8	1.000	0.028	0.166	0.191	3
72	13.2	1.000	0.023	-	-	0
73	37.9	0.902	0.051	0.536	1.291	1
74	36.3	0.963	0.059	0.593	1.324	4
75	116.5	0.920	0.105	0.804	1.026	6
76	85.6	0.823	0.032	0.469	0.376	8
77	73.7	0.471	0.019	0.162	0.247	8
78	175.9	1.000	0.177	0.720	1.533	10
79	369.7	0.959	0.171	0.747	0.572	38
80	2544.9	0.883	0.995	0.877	1.389	104
81	2216.6	0.687	0.850	0.671	1.459	79
82	3625.6	0.754	1.481	0.743	2.100	74
83	2220.0	0.679	1.691	0.677	2.129	59
84	2055.0	0.626	0.764	0.618	1.589	46
85	1967.2	0.676	0.835	0.648	1.723	54
86	628.7	0.992	0.481	0.895	1.108	45
87	1910.8	0.947	1.080	0.929	1.352	115
88	3104.7	0.984	1.101	0.967	1.299	224
89	1506.8	0.990	0.814	0.929	1.137	121
90	725.0	0.881	0.826	0.802	1.065	69

Table 9.6. Canadian trawl catch (t) of Pacific ocean perch, the proportion of the trawl catch with corresponding logbooks (0Pr), the nominal CPUE (OCPUE, t/h), the proportion of the trawl catch meeting the 25% qualification criterion (25Pr), the 25% qualified CPUE (25CPUE, t/h), and the number of records meeting the 25% qualification level in Areas 5E(N) and 5E(S). Data for 1990 are given to July 16.

Year	Catch	0Pr	OCPUE	25Pr	25CPUE	Records
			Area 5E(N)			
77	1.4	1.000	0.072	0.493	0.311	2
78	22.2	1.000	0.147	0.299	0.397	5
79	227.5	1.000	1.226	0.984	1.922	17
80	84.6	1.000	0.709	0.766	1.641	6
81	109.2	0.582	1.962	0.487	2.201	6
82	342.2	0.638	1.517	0.567	1.777	10
83	292.0	0.775	0.564	0.713	1.076	15
84	2186.3	0.838	1.510	0.820	1.828	39
85	1921.2	0.948	0.954	0.891	1.130	45
86	2725.4	0.976	0.839	0.939	1.023	52
87	1129.7	0.928	0.799	0.899	0.893	40
88	1088.8	1.000	0.644	0.944	0.740	44
89	1545.7	1.000	0.745	0.966	0.948	83
90	750.2	1.000	0.880	0.987	1.222	24
			Area 5E(S)			
77	1549.4	0.952	1.416	0.853	2.028	63
78	2413.7	0.972	2.180	0.935	3.050	90
79	839.3	1.000	1.506	0.981	2.189	69
80	877.0	0.539	0.953	0.512	1.351	43
81	599.2	0.722	1.836	0.689	2.394	22
82	614.1	0.988	1.369	0.896	1.783	36
83	835.2	0.913	1.211	0.864	1.787	54
84	840.9	0.545	1.328	0.517	2.015	26
85	828.6	0.729	0.873	0.679	1.240	41
86	641.9	0.738	0.621	0.531	1.117	25
87	660.9	0.837	0.644	0.735	1.017	41
88	766.0	0.945	0.655	0.865	1.090	51
89	571.4	0.997	0.903	0.956	1.196	45
90	402.1	0.975	0.694	0.855	0.955	36

Table 9.7. Canadian trawl catch (t), the proportion of the trawl catch with corresponding logbooks (OPr), the nominal CPUE (OCPUE, t/h), the proportion of the trawl catch meeting the 25% qualification criterion (25Pr), and the 25% qualified CPUE (25CPUE, t/h) for redstripe rockfish, yellowmouth rockfish, and rougheye rockfish in Areas 5E(N) and 5E(S). Data for 1990 are given to July 16.

Year	Area 5E(N)					Area 5E(S)				
	Catch	OPr	OCPUE	25Pr	25CPUE	Catch	OPr	OCPUE	25Pr	25CPUE
					Redstripe rockfish					
77	0.0	-	-	-	-	156.0	1.000	0.343	0.323	0.694
78	0.0	-	-	-	-	231.4	1.000	0.541	0.417	2.302
79	4.8	1.000	0.071	0.026	0.081	72.9	1.000	0.347	0.195	0.559
80	0.0	-	-	-	-	111.0	1.000	0.358	0.583	0.831
81	0.3	1.000	0.067	-	-	132.6	0.611	0.545	0.336	1.254
82	13.3	0.485	0.182	-	-	33.6	0.927	0.148	0.162	0.606
83	18.4	0.170	0.179	-	-	142.8	0.925	0.418	0.534	0.790
84	110.8	0.977	0.196	0.248	1.484	148.5	0.573	0.401	0.305	2.042
85	259.0	1.000	0.225	0.361	0.951	918.7	0.831	1.078	0.776	1.621
86	716.6	0.994	0.280	0.662	1.221	728.2	0.809	0.923	0.630	1.441
87	224.3	0.955	0.226	0.463	0.558	628.9	0.966	0.951	0.882	1.549
88	113.9	1.000	0.094	0.299	0.590	516.8	0.956	0.558	0.794	0.912
89	153.6	1.000	0.186	0.345	0.678	153.7	1.000	0.370	0.508	0.963
90	69.7	1.000	0.153	0.355	0.425	175.8	1.000	0.765	0.864	1.357
					Yellowmouth rockfish					
77	0.0	-	-	-	-	1256.7	1.000	2.156	0.976	2.799
78	0.0	-	-	-	-	1104.6	1.000	1.787	0.778	2.736
79	16.9	1.000	0.241	0.242	0.996	388.5	1.000	1.090	0.846	1.606
80	0.0	-	-	-	-	499.9	0.955	1.484	0.955	1.484
81	2.3	1.000	0.478	1.000	0.478	922.4	0.412	1.978	0.380	2.702
82	67.9	0.804	0.776	0.771	1.434	414.4	0.849	1.047	0.743	1.605
83	52.2	0.351	0.412	0.067	0.387	588.2	0.946	0.967	0.852	1.405
84	72.8	0.866	0.135	0.217	1.061	441.1	0.481	0.632	0.385	0.949
85	179.9	0.965	0.172	0.306	1.360	495.8	0.696	0.566	0.444	0.854
86	615.0	0.989	0.283	0.656	0.789	564.5	0.954	1.047	0.827	1.761
87	108.9	0.968	0.162	0.608	0.738	450.6	0.877	0.554	0.707	1.191
88	107.2	1.000	0.112	0.455	0.553	289.4	0.980	0.347	0.628	1.216
89	157.8	1.000	0.329	0.838	1.081	228.4	1.000	0.530	0.827	0.885
90	143.5	1.000	0.337	0.627	0.980	168.1	0.943	0.495	0.644	0.807
					Rougheye rockfish					
77	0.0	-	-	-	-	76.3	1.000	0.567	0.979	1.132
78	0.0	-	-	-	-	139.5	1.000	0.346	0.754	0.889
79	14.0	1.000	0.100	0.696	0.152	192.1	1.000	0.552	0.830	1.163
80	2.6	1.000	0.061	-	-	51.4	1.000	0.856	0.979	2.183
81	98.1	1.000	3.772	0.960	4.096	9.9	1.000	0.215	0.517	0.715
82	69.1	1.000	0.928	0.950	1.890	274.4	1.000	1.019	0.957	1.681
83	127.5	0.659	0.309	0.340	0.980	74.2	0.827	0.189	0.360	1.214
84	227.0	0.919	0.253	0.412	0.696	100.9	0.727	0.341	0.213	0.889
85	453.7	0.999	0.337	0.685	0.782	157.9	0.733	0.281	0.491	0.435
86	460.8	0.933	0.264	0.575	0.781	268.8	0.616	0.446	0.333	0.566
87	179.9	0.980	0.185	0.499	0.558	296.1	0.880	0.371	0.765	0.547
88	467.0	1.000	0.310	0.711	0.524	353.4	1.000	0.412	0.886	0.671
89	515.5	1.000	0.314	0.752	0.601	251.0	1.000	0.461	0.762	0.926
90	78.9	1.000	0.119	0.513	0.224	179.5	0.977	0.322	0.483	0.519

Table 9.8. Total Canadian rockfish trawl catch (t) in Area 5E(N) and the proportions of Pacific ocean perch, rougheye rockfish, silvergray rockfish, redstripe rockfish, and yellowmouth rockfish in the total catch. Data for 1990 are complete to July 18.

Year	Catch	POP	Rougheye	Silvergray	Redstripe	Yellowmouth
77	5.5	0.258	-	-	-	-
78	48.2	0.461	-	0.326	-	-
79	287.3	0.792	0.049	0.027	0.017	0.059
80	105.1	0.805	0.025	0.147	-	-
81	376.1	0.290	0.261	0.006	0.001	0.006
82	691.5	0.495	0.100	0.054	0.019	0.098
83	568.2	0.514	0.224	0.029	0.032	0.092
84	2995.8	0.730	0.076	0.083	0.037	0.024
85	3200.1	0.600	0.142	0.076	0.081	0.056
86	5031.6	0.542	0.092	0.034	0.142	0.122
87	1880.2	0.601	0.096	0.045	0.119	0.058
88	2134.5	0.510	0.219	0.061	0.053	0.050
89	2871.0	0.538	0.180	0.117	0.053	0.055
90	1277.0	0.587	0.062	0.058	0.055	0.112

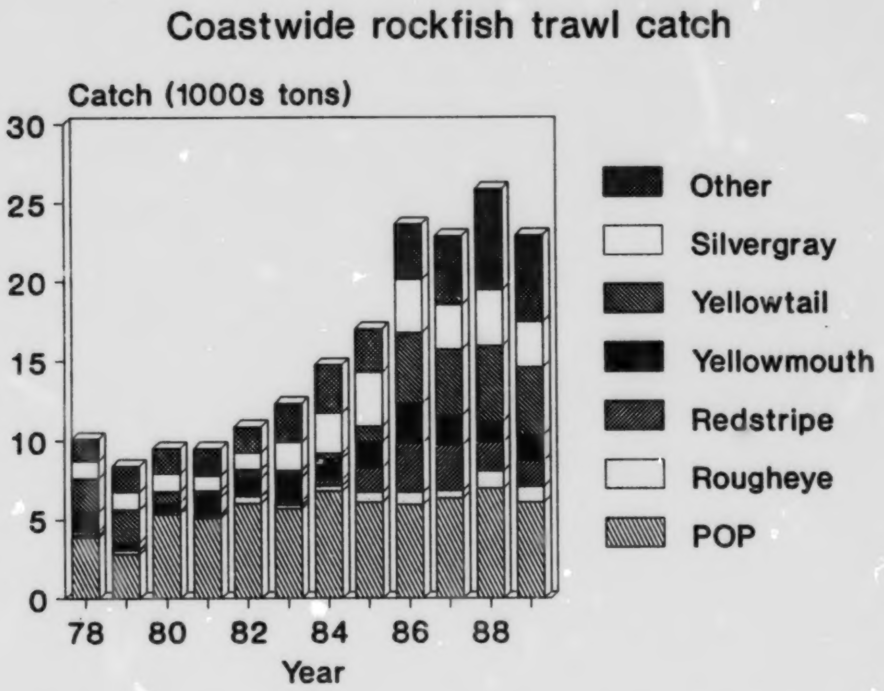
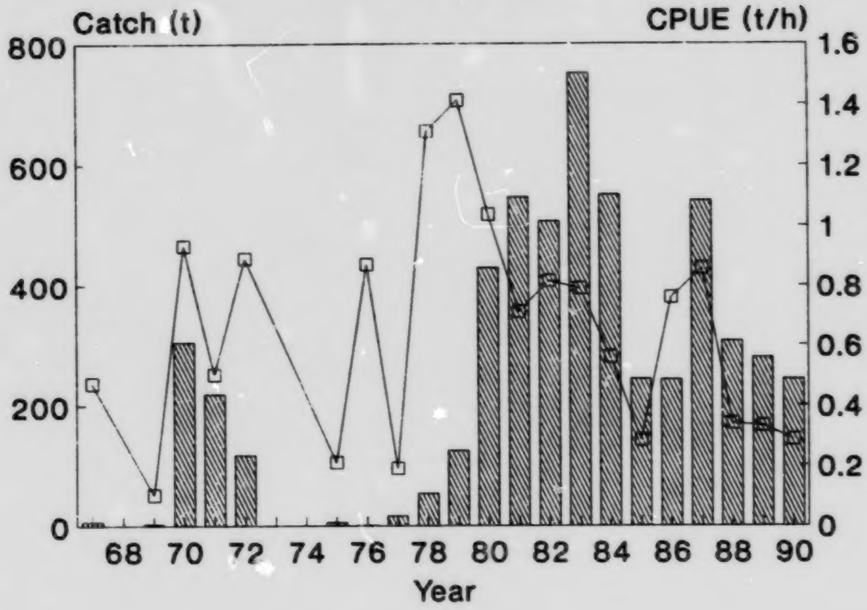


Fig. 9.1. The coastwide rockfish trawl catch between 1978-89, with the major species indicated by the different bar patterns.


Area 3C POP

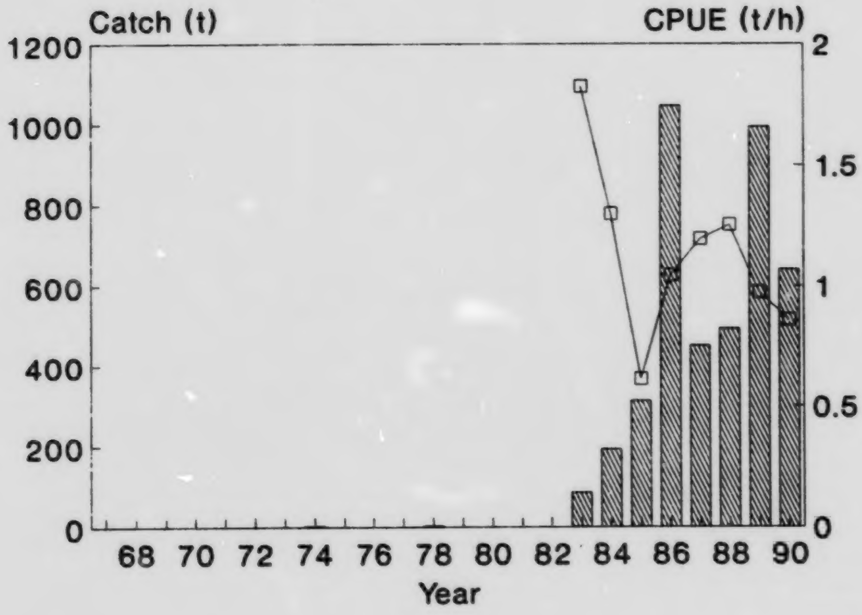

Area 3D POP

Fig. 9.2. The catch (hatched bars) and 25% qualified CPUE (line, open boxes) for Pacific ocean perch in Area 3C (including area 125) and Area 3D (excluding area 125) between 1967-90. Data for 1990 are preliminary to July 16.

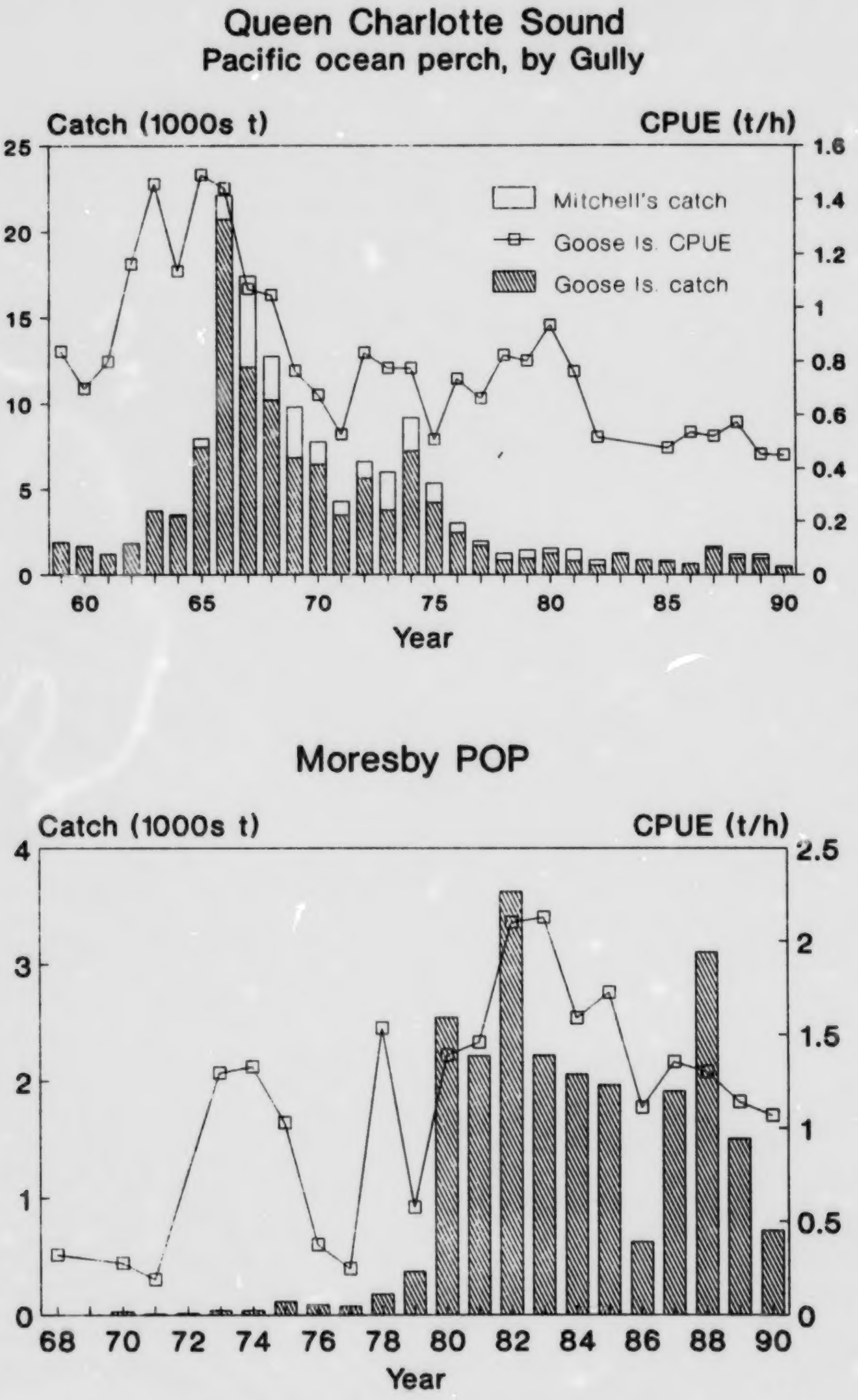
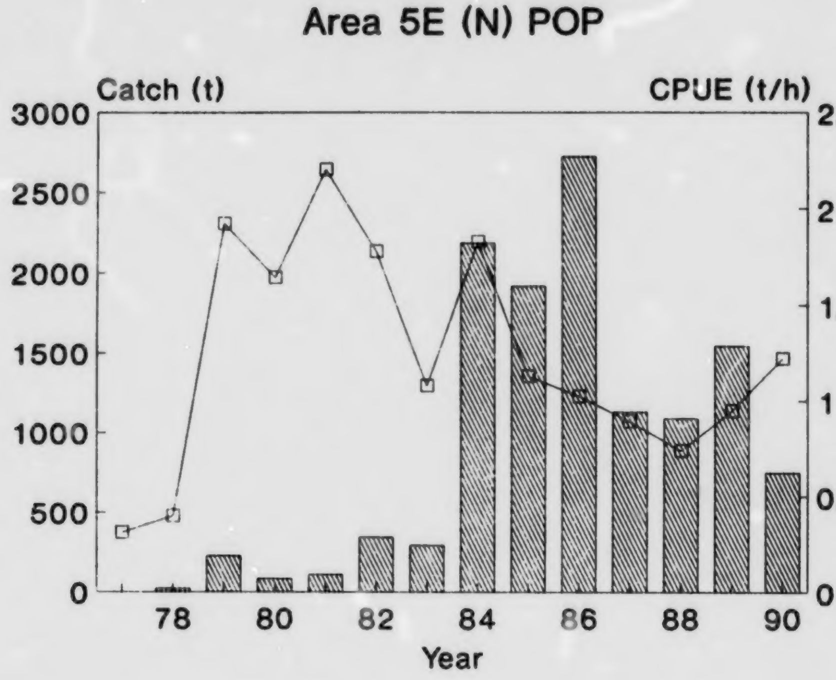


Fig. 9.3. The catch (hatched and open bars) and 25% qualified CPUE (line, open boxes) for Pacific ocean perch in Queen Charlotte Sound and Moresby Gully. Data for 1990 are preliminary to July 1 (Queen Charlotte Sound) or July 16 (Moresby).


Area 5E (N) POP

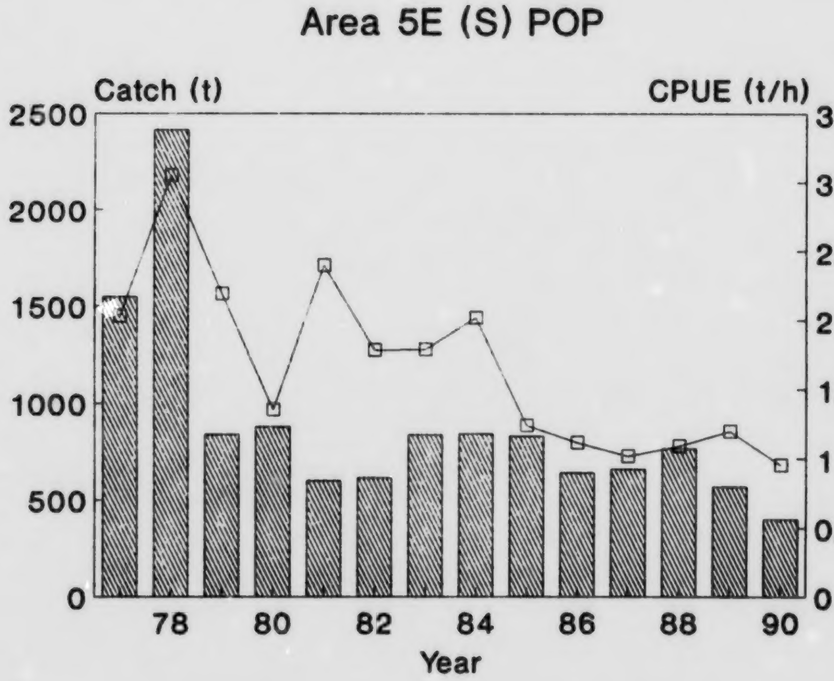
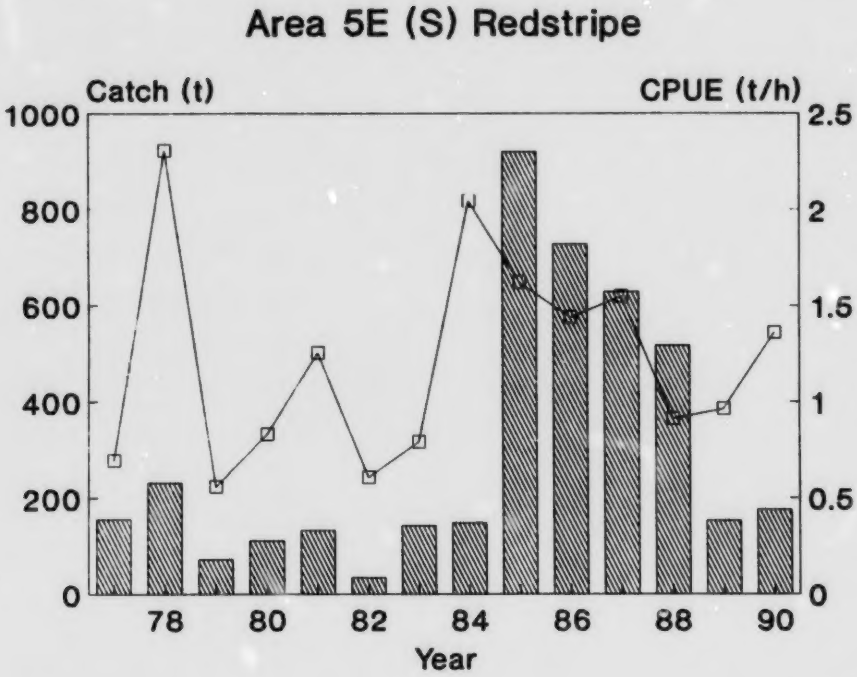

Area 5E (S) POP

Fig. 9.4. The catch (hatched bars) and 25% qualified CPUE (line, open boxes) for Pacific ocean perch in Area 5E(N) and Area 5E(S) between 1977-90. Data for 1990 are preliminary to July 16.



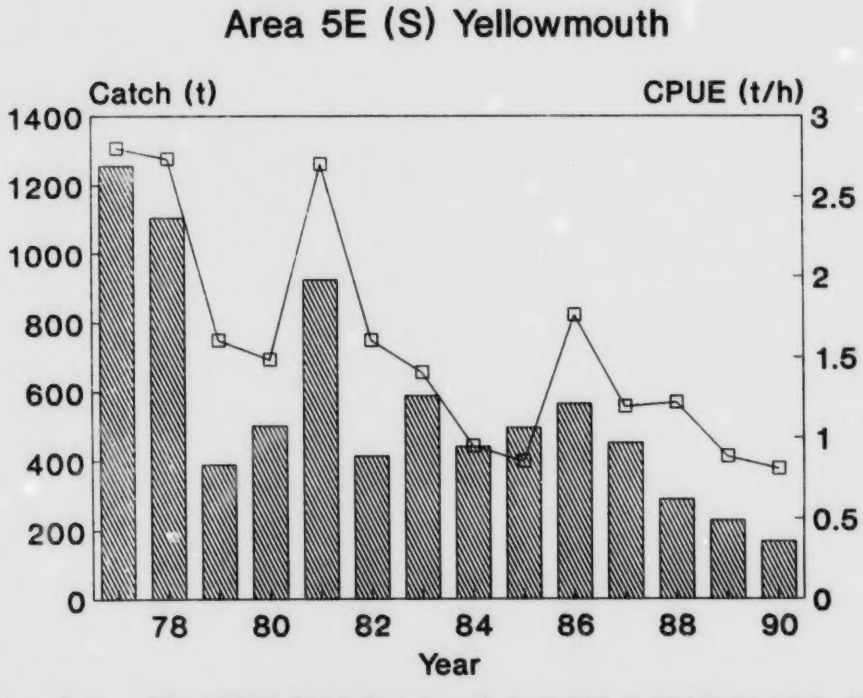


Fig. 9.5. The catch (hatched bars) and 25% qualified CPUE (line, open boxes) for redstripe rockfish and yellowmouth rockfish in Area 5E (S) between 1977-90. Data for 1990 are preliminary to July 16.

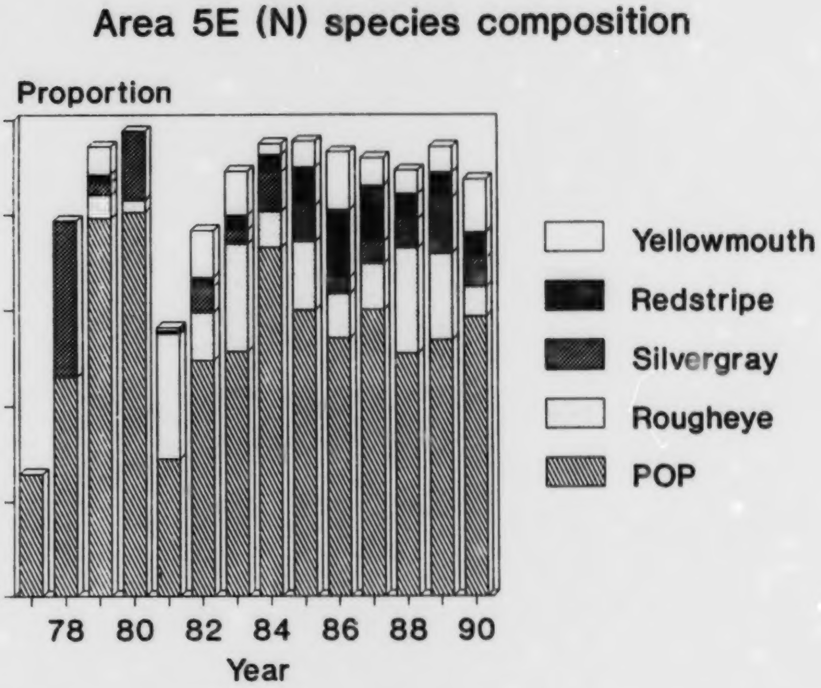


Fig. 9.6. The proportions of Pacific ocean perch and rougheye, silvergray, redstripe, and yellowmouth rockfish comprising the total rockfish trawl catch in Area 5E (N) between 1979-90. Data for 1990 are preliminary to July 16.

10.0. SHELF ROCKFISH (silvergray, yellowtail and canary rockfish)

by R. D. Stanley

The time series of ageing data remain too short and incomplete to conduct catch-at-age analyses for the silvergray and canary rockfish stocks. CPUE and size or age data for these two species are evaluated to assess the impact of the average level of past harvests (Leaman and Stanley 1985, Stanley 1987a, Stanley 1987b, Stanley 1988, Stanley 1989). We have updated the catch-at-age analyses of the central coast yellowtail rockfish fishery and have reviewed a Washington Department of Fisheries (WDF) assessment for the Area 3C population, which is jointly exploited with the U.S.

We explained previously how we estimate standardized CPUE (Stanley 1989) and included examples of the variance about the estimates. The series are re-standardized each year. Nominal CPUE (unstandardized) is shown with the landings data.

We recommend a yield range for each stock (Table 10.1). The lower limit is a conservative estimate of sustainable yield. Yields above the upper limit are unlikely to be sustainable over the longer term. Total landings for these three species of shelf rockfish remain much higher than average (Figure 10.1).

10.1. Coastwide

10.1.1. Silvergray rockfish

The following table shows that the rate of landings of silvergray rockfish within the year has not changed over the last four years. CPUE is down, indicating reduced availability or abundance in 1990. We suggest that potential overruns in 1990 are a result of the size of the initial trip limits.

Year	Data to July 7		Total Catch	Quota
	Catch	CPUE		
87	1459	0.679	2591	*
88	1486	0.507	3141	*
89	1487	0.501	2409	2125
90	1479	0.408	-	1900

*Canary and silvergray rockfish combined quota

We are becoming increasingly concerned about the silvergray stock condition. Based on 1989 data, we have recommended lowering one of the three quotas for 1991. The preliminary 1990 CPUE estimates further support our concerns. The most recent catch estimate (September 21) of 1799 t is already 95% of the 1990 quota.

10.1.2. Yellowtail rockfish

10.1.2.1. Introduction

Stock boundaries for this species remain unresolved. In the interim, we are continuing with the treatment used in the previous document. We treat Queen Charlotte Sound (Q.C.Sd.) separately and then combine the Q.C.Sd. data with data from northern B.C. fisheries and the "Nootka" fishery off the central coast of Vancouver Island. The fishery off the southwest coast of Vancouver Island (Area 3C) is discussed separately (10.3.2).

The Q.C.Sd. scenario uses only 10 years of age observations, a questionable abundance index (commercial CPUE), and spans a period of apparently low exploitation rates. These factors, in conjunction with the longevity of yellowtail rockfish, predetermine the catch-at-age analyses to be preliminary.

10.1.2.2. Landing statistics

The total 1989 B.C. catch was 5102 t, twice the 22-year average (1967-1988) of 2573 t (Table 10.2). The domestic fishery landed 4117 t, with 2382 t from Q.C.Sd., 249 t from the north coast, and 1126 t from the Nootka fishery .

Standardized trawl CPUE for Q.C.Sd. and the central west coast of Vancouver Island appears stable (Table 10.3, Figure 10.2). Midwater trawl CPUE in the latter area declined 50% after one year but has since remained stable at the lower level. CPUE in Q.C.Sd. is elevated over the last 5 years but remains at a low absolute level (ie. 0.5 t/hr). Midwater trawl CPUE for Q.C.Sd. increased about 10% in 1989 to 1.1 t/hr.

10.1.2.3. Stock Delineation

The Yellowtail Rockfish Working Group (DFO and WDF) has initiated joint studies on parasites (Lee, Whitaker and Stanley, in prep.), tissue proteins, and the reproductive biology of yellowtail rockfish to identify stock boundaries. However, as yet no conclusions can be drawn from these studies.

Tag recoveries up to 1988 were reviewed in the previous document. They indicate that, while some individuals travelled from B.C. fishing zones into Washington and Oregon waters, most were caught near the site of release (<100km) after accounting for the relative distribution of effort. Seven more tags were recovered in 1989 and 1990 and have been added to the summary (Table 10.4). All had been at large at least seven years. Of two tagged in Q.C.Sd., one was caught where it was tagged and one was recovered in the Nootka fishery. Of five tagged in Area 3C, four were caught in the same location and one travelled south to the central coast of Washington. In addition, three specimens tagged in southeastern Alaska have been recovered in B.C., two in Hecate Strait and one in the Nootka fishery.

The recent recoveries support the hypothesis of a more widely ranging stock than was previously suggested. Not only do the additional tags add to the number of observations which indicate coastwide mixing, they confirm that the more time provided to disperse after tagging, the broader will be the perceived stock boundaries. The Working Group has proposed a joint coastwide assessment for the 1991 review year.

10.1.2.4 Condition of the Stock

Part A. Q.C.Sound Scenario

Data

The age and length composition data were described in the previous assessment. They now include 10 years of age composition data from 1975-1988 (Table 10.5). Length data are included for 1969, 1974, and 1978.

Model

We used the stock synthesis model, "SSMOD", of Methot (1989b) (see also Methot 1989a, Methot and Hightower 1989). This model offers the practical advantage of being able to use virtually any form of auxiliary data including length data. It offers the theoretical advantage of a "model adapted to the conditions of the database". It explicitly allows for measurement error in any of the input parameters. Reader's are referred to the publications listed above for details on the model's structure.

The model explicitly weights length and age composition information by the number of fish sampled. We altered this such that the data were weighted by the square root of the number of samples rather than the number aged or measured (Kimura 1984, Stanley 1990).

Basic Parameter Template

The basic template of parameters (Appendix Table 10.1) included a terminal F of 0.08 with an emphasis factor for age data of 0.5. Length and effort data had emphasis factors of 0.25. The overall likelihood is the sum of the individual likelihoods owing to different data sources (ie. age, length or effort). The emphasis factors are coefficients which alter the contribution of the component likelihoods. By varying the factors, the model pays more or less attention to the error contributed by different data sources.

This template differs from that used in the previous assessment in that partial recruitment is forced to be an asymptotic function, although the model is allowed to pick the location and slope of the function (Figure 10.3). Previously, we assumed a dome-shaped partial recruitment function. This was changed since it implied, especially for females, fishery refugia for older fish. There is no sampling evidence to support this hypothesis.

Instantaneous natural mortality rates were kept constant, 0.059 for males and 0.1275 for females. They were estimated with the model (F=0.08) but are close to published minimum estimates of 0.06 and 0.14 (Archibald et al. 1981).

In the previous assessment we parameterized ageing error in the previous assessment to fit a linear function. Imprecision rose from 3% aged incorrectly for age 5, to 15% for age 25+. The Working Group conducted a comparison between WDF and DFO ageing laboratories, which indicated about 20% agreement between agencies for a given age. Seventy percent of the differences were within 1 year. We attempted to input this degree of imprecision, however the model tended to assume that every specimen less than 9 years was misaged. While we believe that there is considerable imprecision, we suspect that the error distribution is highly kurtotic. We will attempt to alter the error formulation for subsequent assessments. In the interim, we have used 5% aged incorrectly for age 5, rising to 30% for age 25+.

Model output

Under a variety of assumptions, the model reconstructs the same biomass trend as reported in the previous assessment. Initial biomass declined from the late 1960s to a low in 1981-83 and has been rising since (Figure 10.4). The increase has been caused by strong recruitment starting with the 1975 year-class and particularly the 1977 and 1978 year classes. These large year classes appear to have been produced by relatively low spawning biomasses.

While the biomass trend was identical to that reported in last year's assessment, the log likelihood value maximized at lower initial levels of 30,000-45,000 t (Figure 10.5), instead of more than 60,000 t. We cautioned managers in the previous assessment that the 60,000 t estimate may reflect the preliminary nature of the assessment and suggested that it would probably be reduced with additional data. The lower biomass estimates of the current assessment are also caused because of a change in the partial recruitment function. In the previous assessment, the model accounted for the absence of older females in landings by decreasing partial recruitment among older ages.

The model also indicates a lower biomass because the 1989 CPUE did not increase as predicted from large incoming year classes. This resulted in the model obtaining a better fit throughout with higher F's (i.e. lower biomass). We suspect that with additional data in subsequent years, the model will progressively indicate a smaller original biomass although the changes from year to year will diminish as the model stabilizes.

This year's assessment concentrated on simple univariate sensitivity analyses of the emphasis factors and terminal F. When we varied these parameters, the model was allowed to fit the recruitment which maximized the log likelihood.

Varying emphasis factors

When the model tracked the effort data by using an effort emphasis factor of 1.0 (standard deviation of 10%), the best fit was achieved with a terminal F (1989) of 0.06-0.10 (Figure 10.6). This relatively low estimate of F is logically consistent with the input time series of CPUE (Figure 10.2), which implies a current abundance equal to the initial biomass. It also implies that recent fishing mortality has not been excessive relative to estimates of M (0.06-0.14).

If the effort time series is de-emphasized (emph. = 0.05), the model is being driven by age data. It then maximizes at high values of terminal F (>0.16) (Figure 10.7).

While catch-at-age data without emphasis on effort indicates a high terminal F relative to M, and a declining biomass, it must be noted that we are attempting to run a catch-at-age model without tuning to an index of abundance. The model responds to the increased proportions of young fish by indicating there has been overfishing. Age or size information alone has little capacity for discriminating between high mortality and high recent recruitment especially with a short time series and low terminal F's.

Varying Terminal F

Low terminal F's (0.02-0.04) imply a biomass increase in recent years which is not supported by the CPUE time series. If the CPUE trend is to be believed, then such a low terminal F seems unlikely. High terminal F's (0.16-0.30) lead the model to reconstruct a time series which still indicates a rising population in recent years although much lower than the initial population size. Again, if any credence is attached to the CPUE series, a terminal F equal to or greater than 0.16 is unlikely.

Adjusting the Effort Series

The critical issue in this assessment, regardless of analytical technique, is deciding how much credence should be attached to the CPUE time series. It is the only auxiliary information with which to tune the catch-at-age analysis but there are a variety of obvious reasons for doubting whether catch per trawl hour should reflect abundance for schooling rockfish. They mostly relate to whether catchability is constant. For example, fishing power may have increased over time for reasons not fully accounted for when we standardized by vessel horsepower. It has presumably also increased because of navigational, echo-location and gear technology improvements. We explored this possibility by assuming that catchability was increasing a small amount each year. We did this crudely by altering the effort series such that the effort value was multiplied by compounding rates of 1 or 2%/yr. The results indicate that these compounding rates have little effect on the biomass trends. It would require a rate of 4-5% to alter the conclusions. While this is within the realm of possibility, we have no reason to assume that this would be appropriate. We will explore varying catchability more fully in the next assessment.

Part B. Coastwide analysis (excluding Area 3C)

The second stock scenario combined Q.C.Sd. with the northern B.C. and the Nootka fisheries. We used the same parameter values except that the midwater trawl fishery is treated as a second gear type in the model with slightly different partial recruitment. Unlike the previous assessment, we included the effort time series for bottom trawl in this scenario. We used the standardized CPUE from Q.C.Sd. and total bottom trawl catch from the whole region to calculate total effort.

Since the model uses virtually the same CPUE series, and the additional ageing data from the other fisheries are similar to those for Q.C.Sd., model behaviour is similar. Biomass declines to the middle of the time series then returns to unfished levels in recent years (Figure 10.8). The total likelihood is maximized with a bottom trawl terminal F of 0.083 and a midwater trawl terminal F of 0.074, for a total F of 0.158.

The difference from the Q.C.Sd. case is that it indicates lower initial biomass levels. It tends to attribute the low abundance of late 1970s and early 1980s to the large catches by the Polish midwater fleet in 1975 and 1976. Thus, it attaches more significance to fishing mortality than poor recruitment. Since it is using the same CPUE series, it translates the midwater landings into additional fishing mortality.

These runs also typically suggest that total biomass is now declining and has been since 1986 (Figure 10.8), the recruited biomass is temporarily being sustained by 1970s year-classes (Figure 10.4).

The model behaves the same as the Q.C.Sd. scenario with regard to varying terminal F's and emphasis factors.

10.1.2.5 Stock assessment

Part A. Q.C.Sd.

Although we have added an additional year of ageing data, weighted the biological samples differently, and conducted a more detailed examination of some of the model assumptions, our conclusions about the overall trend are unchanged. Whether Q.C.Sd. should be perceived as a unit stock or an index fishery for a coastal stock, there is little evidence that there has been growth overfishing. Furthermore, since the recently recruiting large year-classes were produced during a period of relatively low spawning biomass, there is little reason to suspect that the stock is in a position to be recruitment overfished.

Conversely, there is little evidence that the stock is grossly underfished. As long as any credence can be assigned to commercial CPUE, the combination of slowly increasing CPUE concurrent with large recruiting year classes indicates that fishing is having a significant impact, otherwise stock abundance would be increasing much more rapidly. At current yield levels, F is close to the mean of the estimate of M for males and females (M=0.10).

In the absence of any demonstrable sign of overfishing, the historical mean harvest of 1440 t from Q.C.Sd. (1967-1988) is again proposed as a conservative harvest level. If the trend in CPUE is believed, it indicates a terminal F in the 0.06-0.10 range. This results in an appropriate level of fishing mortality (i.e. equal to M) and is associated with current harvests of 2300-2400 t.

This range of terminal F's also indicates a current available biomass range of 28,000-45,000 t, approximately equal to the un-fished biomass of 30,000-40,000 t. Gulland (1983) suggests that for many fish, maximum productivity occurs at less than half the unexploited population (i.e. 40% for North Atlantic cod), while for mammals it would exceed that level. If we assume that rockfish are intermediate between the usually shorter-lived fish species and the mammals, then we might assume that the optimal biomass is 50% of unfished biomass. The optimal stock level would then be 15,000-20,000 t. If we assume that optimal harvest is equal to the optimal biomass times the instantaneous natural mortality rate (Alverson and Pereyra 1969), then the equilibrium yield is 1,500-2,000 t (0.10 x 15,000-20,000 t).

The same set of assumptions implies that there may be an "excess" which can be removed to reduce the stock biomass equal to 50% of the un-fished biomass. This ranges from 26,000 for F=0.06 to 13,000 for F=0.10. However, we continue to recommend that managers approach the harvesting of this "possible surplus" with extreme caution.

For reasons explained above, the analysis should still be considered preliminary. Conclusions based on this time series will probably not be stable until we have gathered another 5-10 years of data and even then will only be stable in its estimates of historical population size. Furthermore, even if stock biomass is currently in excess of "optimum" levels, the spawning biomass could be considered as insurance against a prolonged period of poor recruitment.

If it is prudent to exploit this biomass, it should be done gradually. We recommend that a "high-risk" sustainable yield could involve harvesting this surplus at about 5%/yr, or an additional 1000 t/yr. This amortization period of 10-20 years would provide time to reach stability in the assessments. We stress however that the optimum policy may always be to leave any apparent surplus as a hedge against periods of sustained low recruitment. As such, we refer to any quota which includes harvesting a portion of this reserve as "high-risk".

Part B. Coastwide Scenario

We have less confidence in the coastwide analysis. The lack of an appropriate abundance index forces it to be simply an expanded Q.C.Sd. case. We include it to see what direction the additional information tends to force the model. While it still tends to indicate that the stock is in reasonable condition, it is more pessimistic about overall biomass and current exploitation rates. It does, however, indicate that the overall average harvest of 2000 t/yr from the broader region can be considered as a minimum sustainable yield for the combined areas.

10.1.2.6 Yield recommendations

To summarize, the average harvest of 1400 t/yr from Q.C.Sd. has not resulted in overfishing. Our best estimate of stock biomass leads to an estimate of long-term sustainable yield of 1500-2000 t. With the current high stock sizes, harvests of 2300-2400 are associated with estimates of F of 0.06-0.10 and therefore sustainable in the short-term. Finally, we recommend that managers not harvest a portion of the "apparent surplus" until the assessments stabilize. If they do choose to fish down the biomass, then they should do so slowly (ie. <1000 t/yr).

We therefore recommend a harvest range of 1400-3000 t for Q.C.Sd. We recommend a separate "experimental" harvest for the Nootka fishery not to exceed 1000 t (ie. 500-1000 t). If managers request a coastwide (excluding 3C) option, the recommended yield range is 2000 t - 4000 t. This is slightly different than the range of 1900-4600 of the previous assessment.

The differences do not imply that stock abundance has declined, rather it reflects both a more detailed analysis and a different treatment of the apparent "surplus" in biomass.

We suggest that a combined harvest over 3,000 t is likely to reduce stock biomass although it does not necessarily represent overfishing if harvests are lowered after the biomass has been reduced to 50% of unfished abundance.

10.2. Strait of Georgia (Area 4B)

Catches of shelf rockfish are insignificant in the Strait of Georgia.

10.3. West Coast Vancouver Island (Areas 3C+3D)

10.3.1. Silvergray rockfish

10.3.1.1. Landing statistics

Landings were 857 t in 1989 (Table 10.6 and Figure 10.16). The 22-year mean is 560 t (1967-1988). Large harvests from 1977-1979 were mostly from Area 3C(S). There is no general trend in CPUE since the onset of the Canadian domestic fishery in 1982, although there has been a modest decline over the last two years.

10.3.1.2. General biological information

No new ageing information has been collected since the last assessment. Samples collected during the 1985 and 1986 charters indicated a Z for males of 0.136, and 0.155 for females. These are high relative to our best estimates of M of 0.03-0.07 (Archibald et al. 1981).

10.3.1.3. Yield options

While overall CPUE shows no trend, the decline for the last two years, the chronically low CPUE, the complete absence of major fisheries in Canada prior to controlled harvests, and a high Z to M ratio, indicates that the stock cannot sustain harvests in excess of the 22-year mean of 560 t. We continue to recommend a yield range of 400-600 t and note that harvests consistently exceed this range.

10.3.2. Yellowtail rockfish (Area 3C)

10.3.2.1. Introduction

While general stock boundaries remain unknown, the distribution of the fishing grounds and the tagging results provide reasonable evidence that the Canadian fishery of Area 3C(N) and U.S. fisheries of Area 3C(S) and 3B are exploiting the same population (Figure 10.10). Both countries fish the 150-200 m edge on the southern side of the main bank (La Perouse Bank). The U.S. fishery also exploits the mainland edge on the other side of the canyon which separates Areas 3C and 3B (Juan de Fuca Canyon). Much of the catches for both countries comes from within 30 km of the border.

While only one specimen from 3C(N) has been recovered in U.S. waters, over half the recoveries of fish tagged in the general area show either extensive movement along the edge, or travel across the canyon and further south. Since both countries are capturing fish on the edge of the same bank and specimens from this area show considerable mobility, the Yellowtail Rockfish Working Group recommends assessing the 3C-3B area as one stock.

The combined fishery and biological data for this area has recently been examined in extensive detail (Tagart, in prep). The following assessment is a review of that document.

10.3.2.2. Landing statistics

Total harvest from the combined region in 1989 was 2625 t. Average harvest for the entire zone is 1693 t (1967-1988) (Tables 10.7 and 10.8, Figures 10.11 and 10.12). The foreign/JV fishery off Canada alone captured 985 t of the 2625 t. The Polish national and supplemental fishing producing 655 t of this total.

Representative CPUE data are not available from U.S. landings, and Canadian domestic landings are not of sufficient magnitude to provide reliable CPUE estimates.

10.3.2.3. Biological data

Available data indicate that average size and age is declining, although there has been an increase in the last two years (South Vancouver panels, Figure 10.13). Tagart reports that the general decline in size and age has been more pronounced in commercial samples than those collected in the U.S. triennial surveys. No explanation is provided for this discrepancy. Presumably, much of the survey material is from specimens in marginal yellowtail rockfish habitat and is less indicative of the main body of adults than the commercial samples.

10.3.2.4. Survey results

The triennial surveys conducted by National Marine Fisheries Service for the U.S. portion of this area indicate a rapid decline from 1977 to 1980, a smaller decline to 1983 then a further drop to 1986 (Figure 10.14). A survey was conducted in 1989, but the emphasis of the survey has been switched away from rockfish.

10.3.2.5. Stock assessment

Tagart's treatment relies on SSMOD although he includes a comparison with cohort analysis. There are minor differences in how Tagart parameterizes SSMOD in comparison with the above review of the Q.C.Sd. fishery. The most important relates to the treatment of natural mortality and partial recruitment for females. In attempting to account for the truncated age distribution of females, Tagart incorporates increasing age-specific natural mortality in one version. The second version uses a higher, but constant M. Neither form can account completely for the depletion rate of older females, so Tagart allows the model to assume a dome-shaped partial recruitment curve for females. This assumes some form of fishery refugium for older females. This effect is more pronounced for the constant M version which therefore tends to estimate greater abundance. Tagart refers to it as the optimistic case.

The catch-at-age analysis is an exercise of fitting survey estimates, which indicate a rapidly declining biomass, and commercial catch-at-age data, which show decreasing mean age, with survey age composition data, which indicate a stable age composition.

When Tagart attempted to tune the model to the relative decline in survey estimates, it required a terminal F of 1.5. This is not realistic since it results in an exploitable biomass approximately equal to the catch in recent years. However, Tagart suggests that declining survey abundance and mean age support the notion that biomass is declining. This determines that terminal F must exceed at least 0.10 (Figure 10.15). Varying terminal F above 0.10 only alters the magnitude of the decline. Although the likelihood response curve is very flat it tends to indicate a terminal F of 0.15-0.20 for the constant M model. The age-specific M version prefers higher terminal F's. Tagart summarizes the investigation of terminal F's as:

> "The likelihood data imply that 1987 Fs of 0.15 to 0.20 result in the best fit to the model, at least for the constant natural mortality configuration. The fit to fishery age data and survey biomass improves as F_{87} increases; while the fit to survey age deteriorates with increasing F. Estimated F_{87} for the unconstrained constant M model is 0.102, and for the unconstrained age specific M

> model it is 0.179......
>
> .... mean length and mean age have dropped in the Southern Vancouver area, implying a loss of population biomass. .... Among all the stocks analyzed, the trawl survey results in the S. Vancouver area suggest the most severe decline in stock biomass. At fixed values of $F_{87} \geq 0.10$, the S. Vancouver area total and exploitable biomass are declining......
>
> ..... The pessimistic view of stock condition should be taken from runs with F_{87} near 0.20; since, the age specific M model with unconstrained F_{87} estimates 1987 fishing mortality at 0.176, I suggest using this configuration. Estimated total biomass under the age specific M model, is 53,986 t in 1967, 36,639 t in 1977 and drops to 20,641 t by 1990. Exploitable biomass in 1990 is 10,606 t compared to the 18,272 t from the optimistic model. Under the pessimistic model, fishing mortality peaks in 1982 at 0.236, declines to 0.092 by 1985 but rises to 0.213 by 1988 (pp. 242-243).

With forward simulation, he examines the effects of harvesting the stock using the traditional $F_{0.1}$ strategy as well as $F_{0.25}$ and $F_{0.35}$ strategies (harvesting to 25% or 35% of unfished biomass).

Tagart concludes:

> "Yet, the stock synthesis model estimates a much larger biomass than previously estimated for this area. I believe that past estimates of stock condition were conservative. Trends in the mean size and age data which seemed to support the notion of a declining stock biomass now appear to represent the passing of stronger year classes through the fishery. The stock appears to have had above average year classes in 1968-69, 1974-75, and 1977.....
>
> ......I am reluctant to endorse the optimistic view of stock condition, primarily because I have been unable to find any evidence that older female yellowtail rockfish exist. Under the pessimistic view of stock condition, current biomass is lower than that required to support long term sustainable yield. The spawning biomass is in fact only 23% of the unfished spawning biomass, and by most rational standards the stock would be considered overfished. Yet landings over the past 10 years (1980-89) have averaged 2600 t, less than the 2817 t equilibrium yield estimated at $F_{0.35}$. How, then, could the stock have been driven to this low level of abundance? With the unknowns such as they are, it is prudent to be conservative. Therefore, I recommend a 1991 ABC for the S. Vancouver area of 2044 t, derived from the pessimistic model of stock abundance using the

$F_{0.35}$ fishing mortality strategy."

The analysis can be framed in concert with this document by pointing out that average yields of 2600 t are associated with a dramatic drop in U.S. biomass surveys and mean age. While there is some confusing signal from survey age composition and it is impossible to know whether it has been fished to or below the point of optimal yield, it seems reasonable to assume that it cannot continue to sustain 2600 t.

10.3.2.6. Yield recommendations

We view Tagart's recommendation of 2044 t as representing the risk-sustainable yield. From a summary of ABC's for various parameter sets (Table 10.9) , we note that 861 t is the ABC for the most pessimistic scenario and suggest that this level of harvest (i.e. 1000 t) may be appropriate as a conservative yield. This conservatism is based on the alarming decline in the biomass surveys. While we are familiar with the broad confidence bands about the estimates and concur with Tagart's statement that the proportional decline is not congruent with reasonable estimates of terminal F, it represents a major source of concern vis-a-vis historical yields of 2600 t. Our recommended yield range is 1000-2000 t.

10.3.2.7. Management recommendations

The issue of joint harvest seems adequately summarized by Tagart (p.266-267):

> "Among the goals of this analysis is an estimation of the proportion of the Southern Vancouver area yield which can be justifiably harvested in the U.S. portion of that area. I pointed out earlier during a discussion of the stocks that there is tagging data which indicates movement of yellowtail rockfish across the Canada/U.S. provisional boundary. Because of this it is nearly impossible to make a convincing case that fish exploited on the U.S. side of that boundary are unique and separate from those exploited in Canada. Consequently, an estimate of biomass in the U.S. zone derived through age- structured analysis of U.S. catch data only would be erroneous. Such an analysis would simply represent a biased underestimate of available biomass to U.S. fishermen. This stock is clearly a shared stock. As such allocation of the harvestable resource among fishermen becomes a legitimate, although arbitrary, task for fisheries managers. In the last five years, U.S. fishermen landed as much as 74% and as little as 53% of the total harvest [Table 10.7 and Figure 10.19]."

Tagart goes on to recommend using 60% of the southern

Vancouver area allowable catch as an initial allocation to U.S. fishermen. This equals 1200 t. Unlike for example, the offshore hake fishery, there does not yet appear to be any difference in harvesting effects by the two nations. As Tagart points out, the allocation is a matter for arbitration.

To assist in the process, we have included tables with historical catches. We also comment that as directed foreign fishing declines in the Canadian zone, incidental catches of yellowtail rockfish should decrease. Conversely, there may be additional U.S. exploitation of hake in Area 3C and 3B, and therefore yellowtail rockfish, if large processor-trawlers move to this fishery as anticipated (J. Tagart, pers. comm).

We suggest managers consider the by-catches of yellowtail rockfish in their allocation discussions. We also stress that there are serious problems of mis-reporting of landings by the domestic fisheries of both countries.

10.3.3. Canary rockfish

10.3.3.1. Landing statistics

Landings of canary rockfish were 1154 t in 1989 (Table 10.10) and Figure 10.16), well above the 22-yr average (1967-1988) of 695 t. Most of the landings (63%) occurred after July 1, when trip limits for canary rockfish were 50,000 lb/trip and silvergray rockfish were 20,000 lb/trip. It is likely that some silvergray rockfish landings were mis-reported as canary rockfish landings, but the reported catch ratio for canary to silvergray rockfish was 64%, only slightly above the traditional ratio of 50% (1982-1988). Assuming constant catch proportions, the 1989 estimate might overestimate canary rockfish catches by 100-200 t.

CPUE continues to decline since the advent of a significant Canadian domestic fishery on this stock (1982-1988). Nominal CPUE of 0.46 t/hr for 1989 is low for B.C. trawl rockfish fisheries.

10.3.3.2. General biological information

Biological data were summarized in the previous document. Since that summary, only one sample has been collected but not aged. The length frequency distribution of this sample supported the previous observations of relatively small/young fish.

10.3.3.3. Yield options

The decline in CPUE while observing many small/young fish in the samples continues to imply recruitment failure, overfishing, or both, over the last 10-20 years. Harvests approaching the longterm average of 700 tons are considered excessive. We continue to recommend a yield range of 400-600 t.

10.4. Queen Charlotte Sound (Areas 5A+5B)

10.4.1. Silvergray rockfish

10.4.1.1. Landing statistics

The landings of 809 t of silvergray rockfish in 1989 were the third highest ever for the Canadian domestic fishery and fourth highest overall (Table 10.11 and Figure 10.17). Including landings of 738 t by Japanese trawlers in the 1970's, the mean annual harvest between 1967-1988 was 700 t. CPUE appears relatively stable since the advent of the Canadian domestic fishery in 1978 but has declined the last two years.

10.4.1.2. General biological information

We used length frequency observations from a 1988 charter in the previous document to derive a graphical estimate of F. The estimated value of F was 0.10, approximately 2.5 times our best estimate of an M (0.04). We therefore suggested that previous harvest levels had led to an overfished condition.

These samples have now been aged (Figure 10.18) and show highly truncated age composition (Archibald et al. 1981). The greater resolution provided by ageing information allows us now to partition the catch curve into different periods and regress the derived Z against mean harvest for the corresponding period. In Figure 10.19, the log frequency catch curve is first smoothed with a three-year moving average and then divided into 2 ten-year harvest periods. The slopes of the catch curve are shown for the two periods. These two estimates of Z are converted to F by subtracting the estimate of M=0.04. A theoretical relationship is derived by plotting the two estimates of F against the mean harvest for the corresponding time period (Figure 10.20) and forcing a zero intercept. While the two observations indicate deviation from the theoretical line they do indicate a downward trend. Extrapolating to the point on the X-axis where F=M (0.04) indicates a harvest of 200 t, well below the current harvests of 700-1200 t. One could choose alternative time periods of the catch curve and derive different regressions. A visual examination of Figure 10.19 however indicates that the alternative regressions would still show a downward trend, although the yield corresponding to F=0.04 could range as high as 400 t.

10.4.1.3. Stock assessment

Like most of the other shelf rockfish stocks, the chronically low nominal CPUE and lack of major landings throughout the history of this fishery, even in the absence of catch restrictions in earlier years, implies a relatively small biomass. The age composition from 1988 samples indicates that exploitation has had a major impact on the stock and is probably not sustainable at the same level. An argument can be made on the basis of one year's ageing data that the sustainable harvest could be as low as 200 t/yr.

Contrary to the age composition information is the catch history, which shows that this stock has yielded over 700 t/yr for 22 years while CPUE has not shown any dramatic decline over the last 10 years.

10.4.1.4. Yield recommendations

Previous assessments assumed that in the absence of clear signs of overfishing, the mean historical harvest represented a minimum estimate of sustainable yield. The ageing data from 1988 leads us to revise this opinion such that 200 t is now our minimum estimate. Possible errors in this simple catch curve analysis, the fact that the fishery has sustained over 700 t/yr for 22 years, the lack of a trend in CPUE (although an observed decline over the last two years) would argue equally that 700 t/yr could still be considered as sustainable. We certainly see no evidence to suggest that harvests in excess of 700 t are sustainable. We recommend a yield range of 200-700 t. The wide range reflects our uncertainty. but we suspect that as more data becomes available, it will increasingly indicate a sustainable level close to the bottom of this range.

10.4.2. Canary rockfish

10.4.2.1 Landing statistics

Landings equalled 514 t in 1989 (Table 10.12). Annual landings averaged 375 t (1967-1988. CPUE is variable but shows a declining trend from the start of the domestic fishery (Figure 10.21).

10.4.2.2. General biological information

No new additional biological information was collected since the last assessment. We are currently ageing some recent commercial samples. These will be used to recalculate growth rates. Previous use of the length frequency model (Rasmussen and Stanley 1988) indicated that the existing estimate of "L-infinity" is high, causing the model to indicate a 0.0 mortality rate for female canary rockfish.

10.4.2.3. Yield options

Size composition implies that historical yields have had little impact on the stock, but the general trend in CPUE is alarming. The significant increase in CPUE indicated in the previous assessment using partial 1989 data was not apparent after the additional 1989 landings were added. Like other long-established fisheries for silvergray and canary rockfish, the chronically low nominal CPUE (0.25-0.50 t/hr) from grounds that have been extensively fished for a variety of species for over 30 years suggests that there is a relatively small biomass (<10,000 t). This biomass is probably not capable of supporting significantly more yield than the historical average of 375 t.

This historical average continues to be our minimum estimate of sustainable yield. We continue to recommend a yield range of 350-500 t. Recent harvests in excess of 500 t are probably not sustainable unless there is a demonstrable increase in recruitment in coming years.

10.5. Hecate Strait (Area 5C+5D)

10.5.1. Silvergray rockfish

10.5.1.1. Landing statistics

Landings from this stock, which is presumed to reside in Moresby Gully, became significant in 1977 with the advent of a Pacific ocean perch fishery in the southern part of the gully (Table 10.13). Seventy-five per cent of the landings come from a bottom trawl depth range of 120-280 m. Mean landings for 1977-1988 equalled 570 t. Landings in 1989 equalled 743 t.

CPUE has declined significantly since 1985, when landings reached 1000 t/yr (Figure 10.22). The nominal CPUE has now been reduced to levels seen in the longer established canary and silvergray rockfish fisheries to the south.

10.5.1.2. General biological information

No new biological observations are available since the previous assessment. The dramatic recruitment effect seen between 1978 and 1985 precludes using current size or age composition information to estimate mortality rates.

10.5.1.3. Yield options

The sustainable yield option was raised from 300 to 600 t in 1983, prior to any effective quota restrictions, under the suspicion that a significant biomass might be present. We suggested that the option be maintained at that level for 3-5 years while monitoring for signs of fishery impact.

The declining CPUE in recent years would imply that a significant impact has occurred. We suspect that the recent harvests well in excess of 600 tons are unlikely to be sustainable. We no longer assume therefore that an average yield of 500-600 t is the minimum estimate of sustainable yield and suggest that the yield range be lowered from 500-800 to 400-600 t.

10.5.2. Yellowtail and canary rockfish

The yellowtail and canary rockfish fisheries in Hecate Strait continue to be minor. No assessments or yield recommendations are presented.

10.6. West Coast of the Queen Charlotte Islands

The silvergray, yellowtail, and canary rockfish fisheries off the west coast of the Queen Charlotte Islands continue to be relatively minor and incidental to the fisheries for Pacific ocean perch. Yield recommendations are not presented for the incidental fisheries.

Table 10.1. Mean harvest (1967-1988), 1989 landings, status indicators, and suggested yield ranges for silvergray (sil), yellowtail (yel) and canary (can) rockfish.

					Status indicators			
Area	Spec.	Mean harvest (t)	years	1989 landings (t)	Small size/ low ages	Declining size/age	Catch rate	Suggested yield range (t)
3B-3C	yel	401	78-88	1246[a]	yes	yes	yes	1000-2000[b]
3D	yel	2370	86-88	1270	"SSMOD"[c]	"SSMOD"	stable	500-1000
5A+5B	yel	1440	67-88	2381	"SSMOD"[c]	"SSMOD"	stable or increasing	1400-3000
3C+3D	sil	560	67-88	857	yes	unknown	rec. decline	400-600
3C+3D	can	695	67-88	1154	yes	unknown	declining	400-600
5A+5B	sil	700	67-88	809	yes	unknown	rec. decline	200-700
5A+5B	can	375	67-88	514	no	unknown	declining	350-500
5C+5D	sil	570	77-88	743	no	no	declining	400-600

[a] Includes catch in offshore hake fishery.
[b] U.S. and Canada combined.
[c] Analyzed with stock synthesis model

Table 10.2. Yellowtail rockfish landings (t) from B.C. waters, 1967-1989. ("bt" = bottom trawl and "mw" = midwater trawl.)

	West coast Vancouver Island[a]					Q.C. Sound[b]			Northern B.C.		
Year	Can. (bt)	Can. (mw)	U.S. (bt)	Poland (mw)	Offshore hake (mw)	Can. (bt)	Can. (mw)	U.S. (bt)	Can. (bt)	Can. (mw)	Total
1967	4	0	103			19	0	996	1	0	1,123
1968	0	0	23			23	0	278	0	0	324
1969	45	0	243			86	0	2,174	15	0	2,563
1970	29	0	154			160	14	2,629	17	0	3,003
1971	18	0	128			225	0	1,955	51	0	2,377
1972	14	0	76			692	3	2,735	29	0	3,549
1973	26	0	23			516	5	2,735	1	0	3,324
1974	20	0	117			150	14	809	47	1	1,158
1975	13	0	89	6,700		317	97	303	57	0	7,576
1976	86	0	72	2,339		590	38	363	164	31	3,683
1977	77	177	300			762	251	1,242	301	2	3,112
1978	83	13	169		120	1,445	201	397	273	111	2,812
1979	67	66	132		187	1,312	23	192	469	122	2,570
1980	60	8	45		142	471	0	81	124	42	973
1981	44	0	10		120	281	0		86	12	553
1982	134	1			320	280	13		87	12	847
1983	44	9			347	308	15		58	14	795
1984	42	0			350	177	18		86	30	703
1985	353	38			264	341	0		80	129	1,205
1986	1,178	2,354			311	822	0		92	12	4,769
1987	1,039	1,451			330	1,441	101		150	1	4,513
1988	1,190	1,123			334	1,309	986		126	22	5,091
1989	591	896			985	1,499	882		242	7	5,102

[a] Includes landings from Strait of Juan de Fuca.
[b] Excludes landings from Moresby Gully.

Table 10.3. CPUE indices (t/hr) and total effort (h) for the principal domestic fisheries of yellowtail rockfish in B.C. waters[a].

	W.C. Vancouver Island						Q.C. Sound		
	Bottom trawl			Midwater trawl			Bottom trawl		
	Effort[b]	Qualified CPUE[b]	Standardized CPUE[c]	Effort[b]	Qualified CPUE[b]	Standardized CPUE[d]	Effort[b]	Qualified CPUE[b]	Standardized CPUE[c]
1972	-	-	-	-	-	-	1102	0.53	0.49
1973	-	-	-	-	-	-	936	0.53	0.50
1974	-	-	-	-	-	-	270	0.35	0.31
1975	-	-	-	-	-	-	829	0.32	0.30
1976	-	-	-	-	-	-	1347	0.29	0.30
1977	-	-	-	-	-	-	2449	0.25	0.25
1978	-	-	-	-	-	-	2493	0.51	0.47
1979	-	-	-	-	-	-	1759	0.68	0.59
1980	-	-	-	-	-	-	993	0.38	0.32
1981	-	-	-	-	-	-	570	0.33	0.33
1982	-	-	-	-	-	-	639	0.28	0.30
1983	-	-	-	-	-	-	428	0.44	0.46
1984	-	-	-	-	-	-	441	0.24	0.26
1985	322	0.80	0.73	-	-	-	557	0.45	0.49
1986	1013	0.63	0.61	1036	2.01	1.93	1341	0.46	0.47
1987	765	0.73	0.72	1201	1.06	1.02	1958	0.38	0.39
1988	930	0.79	0.78	945	1.18	1.10	2409	0.37	0.43
1989	709	0.64	0.64	853	1.11	1.11	2637	0.49	0.49

[a] Time series of catch rate indices initiated once landings became significant (>250 t).
[b] 25% qualification for interviewed landings.
[c] Standardized for horsepower class and a non-linear relationship of catch and effort.
[d] Standardized for horsepower class.

Table 10.4. Summary of yellowtail rockfish movements from DFO tag recoveries to Aug. 1, 1990.

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1. 4622 tags were released in Q.C. Sound in 1980 and 1981. 5 have been recovered (0.11%). Of these:

    2 - did not move (<10 km);
    1 - travelled 70 km to the northwest, going from the "Southeast Edge" to "Northwest Corner" of the Goose Island Bank;
    2 - travelled 15-20 km to the south, going from "Southeast Edge" of Goose Island Bank to Cape Scott Spit;
    1 - travelled south > 300 km, going from Southeast Edge of Goose Island Bank to the Big Bank area off the Southwest coast of Vancouver Island.
    1 - travelled south (~200km) to central West Coast Vancouver Island.

2. 9417 tags were released off the southwest coast of Vancouver Island in 1980 and 1981. 24 have been recovered with locality information, 1 without (0.26%). Of these:

    16 - did not move ($\leq$ 10km);
    5 - travelled south a short distance ($\bar{x}$ = 23km), to the northern coast of Washington State;
    6 - travelled south to the south coast of Washington State ($\bar{x}$ = 140 km);
    1 - travelled east (23km) into the Strait of Juan de Fuca;
    1 - travelled south to southern Oregon (>500 km).

Table 10.5a. Proportions of male yellowtail rockfish at age from Q.C. Sound samples (all samples for each year standardized to 1000 kg).

						Year							
Age	75	76	77	78	79	80	81	82	83	84	85	86	87	88
5	.000	.000	.000	-	.000	.000	-	.000	.007	-	.000	.000	-	.004
6	.000	.003	.000	-	.000	.000	-	.006	.000	-	.019	.015	-	.004
7	.000	.004	.021	-	.005	.000	-	.000	.000	-	.111	.039	-	.016
8	.000	.007	.048	-	.008	.004	-	.006	.014	-	.081	.161	-	.069
9	.021	.011	.027	-	.018	.016	-	.014	.045	-	.106	.167	-	.042
10	.021	.037	.035	-	.038	.075	-	.024	.017	-	.056	.121	-	.089
11	.083	.054	.007	-	.085	.071	-	.024	.007	-	.068	.088	-	.081
12	.083	.068	.034	-	.043	.060	-	.061	.048	-	.012	.051	-	.038
13	.186	.086	.020	-	.059	.064	-	.073	.075	-	.037	.038	-	.055
14	.146	.141	.047	-	.064	.030	-	.091	.088	-	.050	.018	-	.034
15	.021	.096	.053	-	.054	.034	-	.037	.030	-	.037	.009	-	.022
16	.021	.061	.068	-	.054	.030	-	.018	.053	-	.037	.018	-	.012
17	.021	.025	.061	-	.059	.041	-	.018	.017	-	.025	.012	-	.026
18	.021	.046	.021	-	.044	.045	-	.037	.047	-	.012	.009	-	.055
19	.021	.043	.021	-	.049	.041	-	.031	.024	-	.019	.012	-	.046
20	.021	.029	.035	-	.034	.072	-	.067	.041	-	.050	.009	-	.030
21	.021	.025	.028	-	.032	.019	-	.055	.036	-	.025	.012	-	.012
22	.000	.025	.021	-	.015	.015	-	.031	.067	-	.050	.006	-	.016
23	.000	.036	.034	-	.027	.030	-	.018	.046	-	.068	.006	-	.038
24	.021	.018	.028	-	.015	.019	-	.024	.030	-	.037	.015	-	.022
25	.042	.036	.027	-	.022	.011	-	.031	.024	-	.000	.023	-	.026
26	.000	.018	.014	-	.015	.015	-	.031	.017	-	.000	.017	-	.046
27	.083	.021	.034	-	.017	.026	-	.006	.029	-	.000	.009	-	.069
28	.000	.025	.054	-	.015	.011	-	.018	.003	-	.006	.009	-	.012
29+	.167	.085	.262	-	.228	.261	-	.269	.235	-	.094	.136	-	.138

Table 10.5b. Proportions of female yellowtail rockfish at age from Q.C. Sound samples (all samples for each year standardized to 1000 kg).

Age	75	76	77	78	79	80	Year 81	82	83	84	85	86	87	88
5	.000	.000	.000	-	.000	.000	-	.000	.000	-	.000	.004	-	.000
6	.000	.000	.000	-	.005	.000	-	.000	.000	-	.029	.027	-	.000
7	.000	.009	.103	-	.000	.000	-	.028	.061	-	.101	.047	-	.065
8	.000	.018	.039	-	.016	.008	-	.028	.100	-	.123	.184	-	.122
9	.019	.018	.082	-	.011	.008	-	.056	.059	-	.198	.265	-	.065
10	.019	.072	.104	-	.085	.136	-	.000	.009	-	.167	.128	-	.187
11	.019	.099	.039	-	.084	.190	-	.167	.139	-	.072	.136	-	.122
12	.038	.118	.060	-	.114	.236	-	.192	.100	-	.065	.084	-	.049
13	.271	.088	.099	-	.089	.122	-	.056	.148	-	.058	.042	-	.065
14	.250	.216	.178	-	.094	.015	-	.083	.160	-	.065	.011	-	.033
15	.192	.221	.098	-	.082	.038	-	.111	.117	-	.029	.004	-	.016
16	.038	.063	.121	-	.077	.053	-	.056	.019	-	.051	.019	-	.049
17	.096	.018	.039	-	.057	.053	-	.028	.000	-	.007	.007	-	.049
18	.058	.025	.019	-	.077	.038	-	.083	.030	-	.007	.011	-	.016
19	.000	.000	.019	-	.040	.015	-	.000	.000	-	.007	.004	-	.049
20	.000	.008	.000	-	.041	.022	-	.000	.000	-	.007	.004	-	.000
21	.000	.000	.000	-	.020	.015	-	.056	.040	-	.007	.004	-	.000
22	.000	.018	.000	-	.011	.007	-	.028	.009	-	.007	.004	-	.016
23	.000	.000	.000	-	.020	.000	-	.000	.000	-	.000	.000	-	.016
24	.000	.000	.000	-	.015	.000	-	.000	.000	-	.000	.000	-	.000
25	.000	.000	.000	-	.010	.007	-	.000	.000	-	.000	.000	-	.000
26	.000	.000	.000	-	.010	.000	-	.000	.000	-	.000	.004	-	.016
27	.000	.000	.000	-	.015	.000	-	.000	.000	-	.000	.004	-	.016
28	.000	.000	.000	-	.005	.000	-	.000	.000	-	.000	.000	-	.016
29	.000	.009	.000	-	.022	.037	.007	.028	.009	-	.000	.007	-	.032

Table 10.6. Area 3C and 3D landings (t), bottom trawl effort (h), and nominal CPUE (t/h) of silvergray rockfish 1967-1989.

		Total	Interviewed			Interviewed (25% qual.)		
Year	Nat.	landings[a]	Landings[b]	Effort[c]	CPUE	Landings	Effort	CPUE
1967	USA	196	195	4471	.04	-	-	-
1968	USA	205	200	2928	.07	-	-	-
1969	USA	334	334	3647	.09	-	-	-
1970	Can	2	2	119	.02	1	1	1.00
	USA	371	358	4785	.07	-	-	-
1971	Can	5	5	48	.10	2	2	1.00
	USA	161	161	3009	.05	-	-	-
1972	USA	442	442	2969	.15	-	-	-
1973	USA	227	227	2619	.09	-	-	-
1974	Can	1	1	12	.08	-	-	-
	USA	236	235	2666	.09	-	-	-
1975	Can	4	4	44	.09	0	0	-
	USA	113	113	2938	.04	-	-	-
1976	Can	5	5	9	.55	0	0	-
	USA	326	326	3945	.08	-	-	-
1977	Can	28	28	516	.05	17	28	.61
	USA	1035	1035	5427	.19	-	-	-
1978	Can	22	22	284	.08	1	8	.13
	USA	972	972	6244	.16	-	-	-
1979	Can	22	22	131	.17	13		
	USA	1248	1248	4812	.26	-	-	-
1980	Can	23	23	214	.11	9	15	.60
	USA	764	764	3848	.20	-	-	-
1981	Can	15	15	77	.19	9	24	.38
	USA	284	284	5424	.05	-	-	-
1982	Can	129	129	388	.33	124	126	.99
	USA	60	60	11,819	.01	-	-	-
1983	Can	646	646	1455	.44	390	837	.47
1984	Can	570	335	1644	.20	237	658	.36
1985	Can	921	349	1242	.28	273	521	.52
1986	Can	1093	690	3135	.22	474	906	.52
1987	Can	604	516	2199	.24	323	458	.72
1988	Can	1197	1007	3878	.26	644	1217	.53
1989	Can	857	845	5001	.17	540	1177	.46

[a] U.S. total landings equals Washington and Oregon combined.

[b] U.S. interviewed landings from Washington only (Tagart and Kimura 1982).

[c] U.S. interviewed effort represents total rockfish effort from Washington only (Tagart and Kimura 1982).

Table 10.7. Estimated yellowtail rockfish landings (t) by target fishery from Area 3C-3B, 1967-89

	Canada		U. S.				
Year	Domestic	Foreign/JV	Domestic	Shrimp	Foreign/JV	Total	%Canada
1967	1	0	59	0	302	362	0.3
68	0	0	952	0	544	1496	0.0
69	22	0	1516	4	587	2129	1.0
70	10	0	486	0	185	681	1.5
71	10	0	366	0	107	483	2.1
72	11	0	462	0	268	741	1.5
73	21	0	276	5	332	634	3.3
74	17	0	58	37	629	741	2.3
75	6	0	82	38	135	261	2.3
76	50	0	952	68	55	1125	4.4
77	237	0	1287	72	0	1596	14.8
78	44	120	1357	112	8	1641	10.0
79	40	187	1381	318	0	1926	11.8
80	37	142	2029	231	38	2477	7.2
81	20	120	2900	238	57	3336	4.2
82	115	320	3342	85	381	4243	10.3
83	16	347	2890	256	268	3777	9.6
84	20	350	980	60	70	1480	25.0
85	94	264	943	46	49	1396	25.6
86	430	311	1536	43	95	2415	30.7
87	501	330	1188	15	61	2095	39.7
88	280	334	1529	14	50	2207	27.8
89	260	984	1337	5	39	2625	47.4

Table 10.8. Observer estimates of yellowtail rockfish catch in the 1989 offshore hake fishery, in B.C. waters.

	Fishery				
Nation	Joint-Venture	National	Supplemental	Total	%
Japan	68.0	–	–	68.0	6.9
Poland	90.0	583.8	72.3	746.1	75.7
U.S.S.R.	92.9	72.6	5.5	171.0	17.4
Total	250.9	656.4	77.8	985.1	100.0

Table 10.9. Stock synthesis estimates of equilibrium biomass (t), recruitment (thousands of fish), yield and 1991 acceptable biological catch for the Southern Vancouver area (from Tagart 1990).

B-H Param. A	F Strategy[a]	B^* (t)	SPB^* (t)	R (x1000)	Y^* (t)	F	SPB^*/SPB_0^*	ABC_{91}
OPTIMISTIC SCENARIO: CONSTANT M, F_{87}=0.102								
0.659	MSY	32633	11212	4127	1349	0.070	0.423	1364
	0.35	2734	695	444	220	0.160	0.026	3001
	0.25	0	0	0	0	0.220	0.000	4023
0.889	MSY	27791	7831	4781	2296	0.150	0.295	2826
	0.35	28446	7183	4656	2292	0.160	0.271	3001
	0.25	19875	4137	3779	2063	0.220	0.156	4023
1.000	0.1	29643	6995	6047	3258	0.210	0.264	3857
	0.35	34061	9328	6047	2976	0.160	0.352	3001
	0.25	28924	6620	6047	3301	0.220	0.250	4023
PESSIMISTIC SCENARIO: AGE SPECIFIC M, F_{87}=0.176								
0.659	MSY	23164	4275	3810	1287	0.090	0.419	861
	0.35	1307	169	266	134	0.225	0.017	2044
	0.25	0	0	0	0	0.320	0.000	2806
0.889	MSY	20321	3029	4442	2167	0.205	0.297	1876
	0.35	20987	2715	4295	2157	0.225	0.266	2044
	0.25	15143	1608	3522	1934	0.320	0.158	2806
1.000	0.1	24518	3480	5609	2836	0.230	0.341	2085
	0.35	24733	3545	5609	2817	0.225	0.348	2044
	0.25	21445	2561	5609	3080	0.320	0.251	2806

[a] MSY, the fishing mortality which produces the maximum equilibrium yield, i.e., F_{msy};

0.1, the fishing mortality at the point of contact between a tangent to the yield versus fishing mortality curve whose slope is equal to 10% of the slope near F=0, i.e., $F_{0.1}$;

0.35, the fishing mortality which causes equilibrium spawning biomass per recruit to be approximately 35% of the unfished spawning biomass, i.e, $F_{0.35}$;

0.25, the fishing mortality which causes equilibrium spawning biomass per recruit to be approximately 25% of the unfished spawning biomass, i.e., $F_{0.25}$.

Table 10.10. Area 3C and 3D landings (t), bottom trawl effort (h), and nominal CPUE (t/h) of canary rockfish, 1967-89.

			Interviewed (0% qual.)			Interviewed (25% qual.)		
Year	Nat.	Total landings[a]	Landings[b]	Effort[c]	CPUE	Landings	Effort	CPUE
1967	USA	578	575	4,471	.13	-	-	-
	Can	4	4	41	.10	1	8	.12
1968	USA	938	902	2,838	.32	0	0	-
	Can	19	19	157	.12	10	12	.83
1969	USA	779	746	3,647	.20	-	-	-
	Can	46	46	266	.17	42	127	.33
1970	USA	990	938	4,785	.20	-	-	-
	Can	18	18	96	.19	17	89	.19
1971	USA	1,011	962	3,009	.32	-	-	-
	Can	66	66	533	.12	52	235	.22
1972	USA	294	292	2,969	.10	-	-	-
1973	USA	493	490	2,619	.19	-	-	-
1974	Can	26	26	461	.06	15	26	.58
	USA	607	605	2,666	.23	-	-	-
1975	Can	14	14	186	.08	9	10	.90
	USA	658	658	2,938	.22	-	-	-
1976	Can	193	193	822	.23	157	207	.76
	USA	395	395	3,945	.10	-	-	-
1977	Can	196	196	1,808	.12	109	147	.74
	USA	358	358	5,427	.07	-	-	-
1978	Can	68	68	434	.16	40	56	.71
	USA	1,063	1,063	6,244	.17	-	-	-
1979	Can	122	114	680	.17	94	175	.54
	USA	315	315	4,812	.07	-	-	-
1980	Can	126	126	1,058	.12	109	204	.53
	USA	477	477	3,848	.12	-	-	-
1981	Can	66	66	929	.07	42	84	.50
	USA	249	249	5,424	.05	-	-	-
1982	Can	316	316	1,415	.22	286	309	.93
	USA	133	133	11,819	.01	-	-	-
1983	Can	853	647	1,723	.38	593	1,049	.57
1984	Can	1,189	947	1,079	.46	916	1,170	.78
1985	Can	903	611	1,897	.32	557	779	.72
1986	Can	722	529	2,841	.19	344	651	.53
1987	Can	695	600	2,535	.24	462	670	.69
1988	Can	313	291	2,085	.14	176	516	.34
1989	Can	1173	1154	6,520	.18	854	1862	.46

[a] U.S. total landings equals Washington and Oregon combined.

[b] U.S. interviewed landings from Washington only (Tagart and Kimura 1982).

[c] U.S. interviewed effort represents total rockfish effort from Washington only (Tagart and Kimura 1982).

Table 10.11. Area 5A and 5B landings (t), bottom trawl effort (h), and CPUE (t/h) of silvergray rockfish, 1967-89.

		Total	Interviewed			Interviewed (25% qual.)		
Year	Nat.	landings[a]	Landings[b]	Effort[c]	CPUE	Landings	Effort	CPUE
1967	CAN	87	89	539	.17	63	200	.32
	USA	397	396	9,431	.04	-	-	-
1968	CAN	78	78	644	.12	37	109	.34
	USA	933	822	8,488	.10	-	-	-
1969	CAN	78	78	1188	.07	28	152	.18
	USA	1,291	1,276	13,557	.09	-	-	-
1970	CAN	14	14	287	.05	6	29	.21
	USA	189	189	9,264	.02	-	-	-
1971	CAN	16	16	331	.05	6	66	.09
	USA	521	512	7,137	.07	-	-	-
1972	CAN	54	54	654	.08	21	108	.19
	USA	251	251	9,224	.03	-	-	-
1973	CAN	40	40	328	.12	33	70	.47
	USA	189	189	9,625	.02	-	-	-
1974	CAN	45	45	412	.11	9	12	.75
	USA	377	377	8,797	.04	-	-	-
1975	CAN	31	31	479	.06	19	61	.31
	USA	306	306	5,179	.06	-	-	-
1976	CAN	172	172	1,914	.09	82	224	.37
	USA	443	443	4,620	.10	-	-	-
1977	CAN	198	198	2,462	.08	123	320	.38
	USA	440	440	5,165	.09	-	-	-
1978	CAN	723	723	4,049	.18	468	1,069	.44
	USA	57	57	909	.06	-	-	-
1979	CAN	629	629	3,885	.16	429	1,225	.35
	USA	298	298	1,696	.18	-	-	-
1980	CAN	629	625	3,681	.17	495	1,538	.32
	USA	147	147	1,146	.13	-	-	-
1981	CAN	415	415	2,120	.20	340	808	.42
1982	CAN	618	597	4,099	.15	430	1,208	.36
1983	CAN	524	477	3,348	.14	323	1,073	.30
1984	CAN	982	718	3,481	.21	642	1,948	.33
1985	CAN	997	724	3,555	.20	611	1,860	.33
1986	CAN	700	564	3,812	.15	388	1,314	.30
1987	CAN	1,224	1,083	6,509	.17	641	1,596	.40
1988	CAN	1,051	1,016	7,232	.14	596	1,554	.38
1989	CAN	809	779	6,625	.12	425	1,359	.31

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[a] U.S. total landings equals Washington and Oregon combined.

[b] U.S. interviewed landings from Washington only (Tagart and Kimura 1982).

[c] U.S. interviewed effort represents total rockfish effort for Washington only (Tagart and Kimura 1982).

Table 10.12. Area 5A and 5B landings (t), bottom trawl effort (h), and CPUE (t/h) of canary rockfish, 1967-89.

		Total	Interviewed			Interviewed (25% qual.)		
Year	Nat.	landings[a]	Landings[b]	Effort[c]	CPUE	Landings	Effort	CPUE
1967	CAN	41	41	535	.08	13	32	.41
	USA	216	215	9,431	.02	-	-	-
1968	CAN	49	49	576	.09	31	78	.40
	USA	1,034	937	8,488	.11	-	-	-
1969	CAN	67	67	733	.09	37	110	.34
	USA	464	418	13,557	.03	-	-	-
1970	CAN	6	6	80	.08	4	12	.33
	USA	220	220	9,264	.02	-	-	-
1971	CAN	18	18	329	.05	6	8	.75
	USA	207	183	7,137	.03	-	-	-
1972	USA	61	61	9,224	.01	-	-	-
1973	CAN	29	29	119	.24	23	80	.29
	USA	298	298	9,625	.03	-	-	-
1974	CAN	3	3	81	.04	1	7	.14
	USA	257	257	8,797	.03	-	-	-
1975	CAN	23	23	403	.06	15	17	.88
	USA	189	189	5,179	.04	-	-	-
1976	CAN	92	92	1,558	.06	16	49	.33
	USA	447	447	4,620	.10	-	-	-
1977	CAN	121	121	2,356	.05	53	192	.28
	USA	288	288	5,165	.06	-	-	-
1978	CAN	263	263	2,692	.10	101	242	.42
	USA	8	8	909	.01	-	-	-
1979	CAN	308	308	3,070	.10	211	582	.36
	USA	62	62	1,696	.04	-	-	-
1980	CAN	276	276	2,157	.13	198	451	.44
	USA	88	88	1,146	.08	-	-	-
1981	CAN	144	144	1,636	.09	69	201	.35
1982	CAN	358	330	3,203	.10	210	706	.30
1983	CAN	343	299	2,851	.11	152	454	.33
1984	CAN	507	321	2,506	.13	228	686	.33
1985	CAN	391	281	2,823	.10	162	553	.29
1986	CAN	262	211	2,931	.07	64	253	.25
1987	CAN	560	510	4,248	.12	245	572	.43
1988	CAN	544	529	5,792	.09	195	652	.30
1989	CAN	514	501	5,419	.09	238	611	.39

[a] U.S. total landings equals Washington and Oregon combined.

[b] U.S. interviewed landings from Washington only (Tagart and Kimura 1982).

[c] U.S. interviewed effort represents total rockfish effort for Washington only (Tagart and Kimura 1982).

Table 10.13. Area 5C and 5D landings[a] (t), bottom trawl effort (h), and CPUE (t/h) of silvergray rockfish, 1971-89.

		Interviewed			Interviewed (25% qual.)		
Year	Total landings	Landings	Effort	CPUE	Landings	Effort	CPUE
1971	34	34	229	.15	24	121	.20
1972	61	61	232	.26	44	54	.81
1973	10	10	147	.07	-	-	-
1974	13	13	64	.20	11	34	.33
1975	11	11	190	.06	4	5	.79
1976	118	118	1,440	.08	55	414	.13
1977	232	232	2,019	.12	142	468	.30
1978	235	235	1,413	.17	177	301	.59
1979	429	429	3,029	.14	285	701	.41
1980	346	344	1,938	.18	186	396	.47
1981	456	415	1,762	.24	343	311	1.10
1982	259	238	1,799	.13	149	212	.70
1983	451	348	1,108	.31	289	337	.86
1984	647	383	2,081	.18	315	710	.44
1985	1,043	729	2,133	.34	578	458	1.26
1986	1,082	1,056	1,796	.59	1,024	927	1.10
1987	763	632	1,928	.33	531	592	0.90
1988	893	881	3,270	.27	625	1,064	0.59
1989	743	741	2,731	.27	538	1,063	0.51

[a] No history of U.S. fishing on this stock.

Table 10.14. Area 5E-N and 5E-S landings (t), bottom trawl effort (h), and CPUE (t/h) of silvergray rockfish, 1977-89.

Year		Total	Interviewed			Interviewed (25% qual.)		
		landings	Landings	Effort	CPUE	Landings	Effort	CPUE
1977	S	20	20	136	.15	0	0	-
	N	0	0	0	-	0	0	-
1978	S	124	124	572	.22	56	105	.53
	N	16	16	91	.18	16	21	.76
1979	S	44	44	189	.23	30	19	1.58
	N	8	8	95	.08	0	0	-
1980	S	104	104	246	.42	81	97	0.84
	N	15	15	17	.91	15	17	.91
1981	S	57	22	74	.30	12	12	1.00
	N	2	2	10	.20	0	0	-
1982	S	27	22	152	.14	7	4	1.75
	N	38	30	56	.54	27	9	3.00
1983	S	130	130	414	.31	44	58	.76
	N	16	11	108	.10	1	1	1.00
1984	S	78	71	246	.29	47	104	.45
	N	248	233	731	.32	61	33	1.88
1985	S	212	175	466	.38	85	142	.60
	N	245	245	1,258	.20	158	219	.72
1986	S	295	245	601	.41	112	154	.73
	N	172	170	1,772	.10	35	39	.89
1987	S	113	102	586	.17	30	53	.58
	N	85	83	1,004	.08	6	21	.30
1988	S	255	244	1,001	.24	108	96	1.13
	N	131	131	1,521	.09	40	76	.53
1989	S	120	119	522	.23	50	71	.70
	N	333	333	1,555	.21	188	361	.52

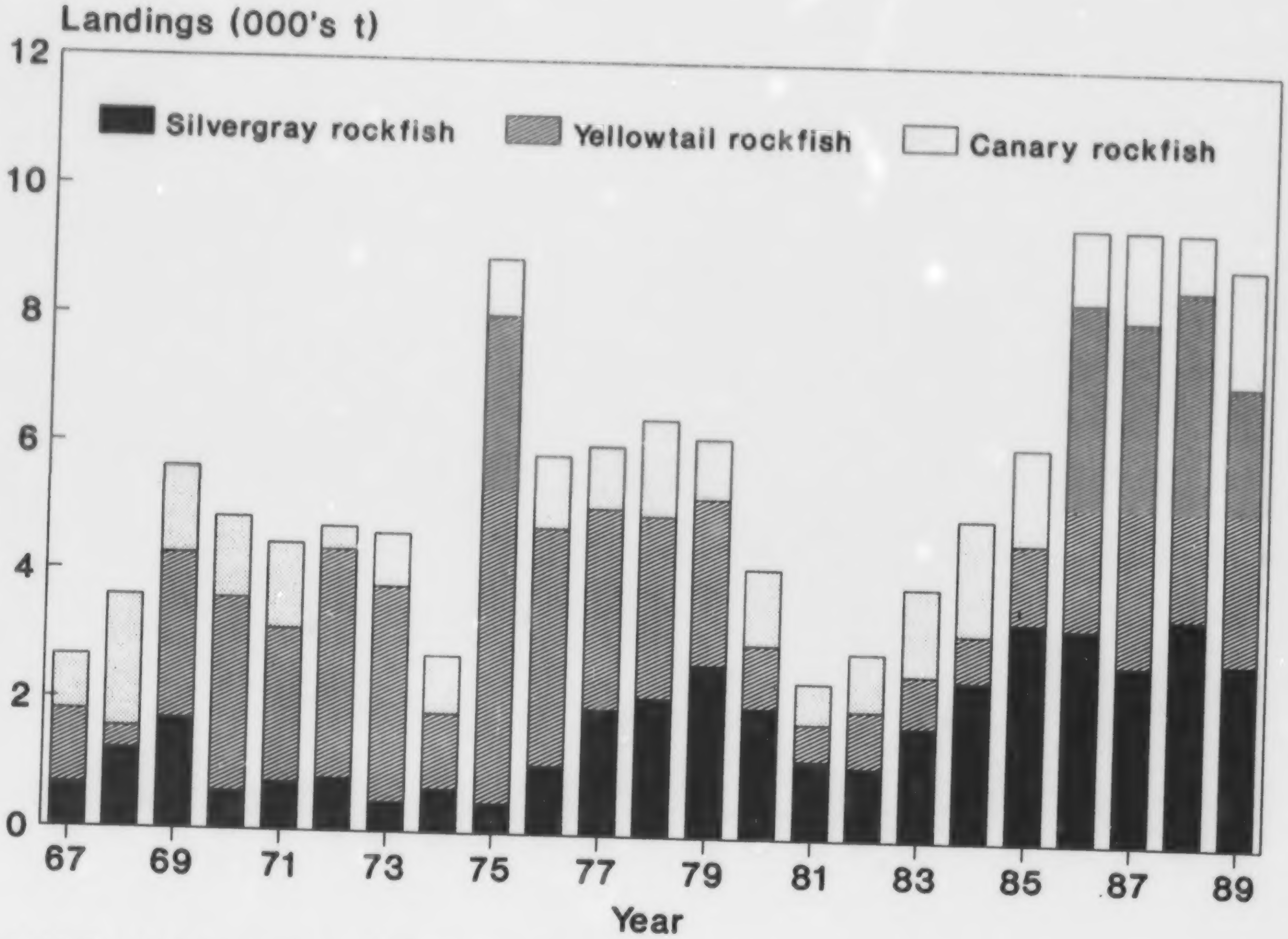

Fig. 10.1. Combined shelf rockfish landings under quota from B.C. waters.

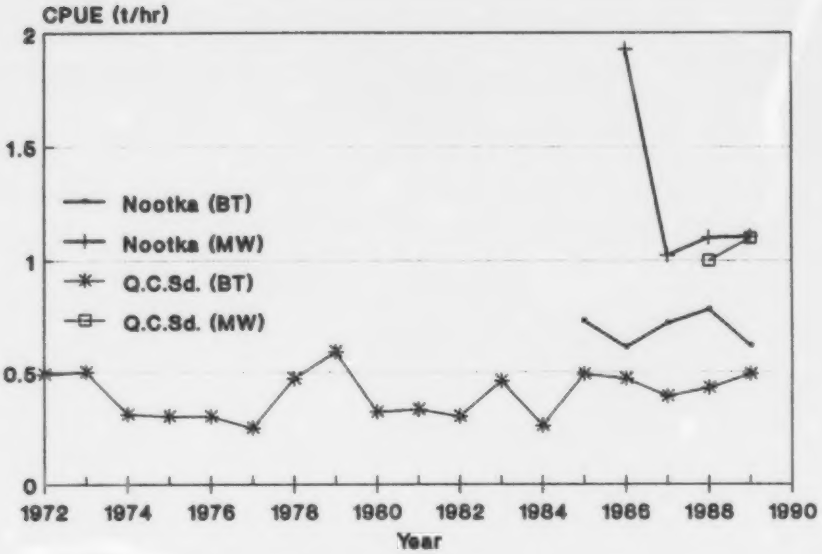

Fig. 10.2. Yellowtail rockfish CPUE in Canadian Waters.

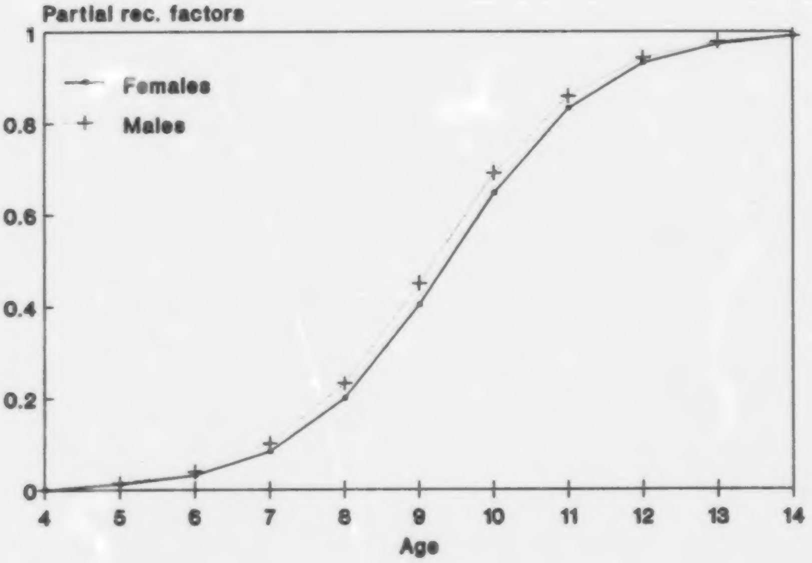

Fig. 10.3. Yellowtail rockfish, Q.C.Sd., partial recruitment factors for bottom trawl.

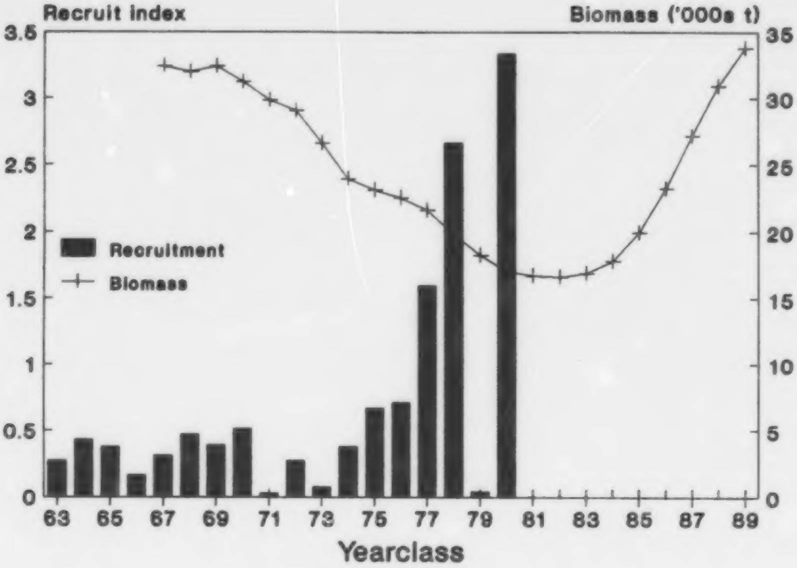

Fig. 10.4. Yellowtail rockfish, Q.C.Sd., recruitment index and available biomass (F=0.08).

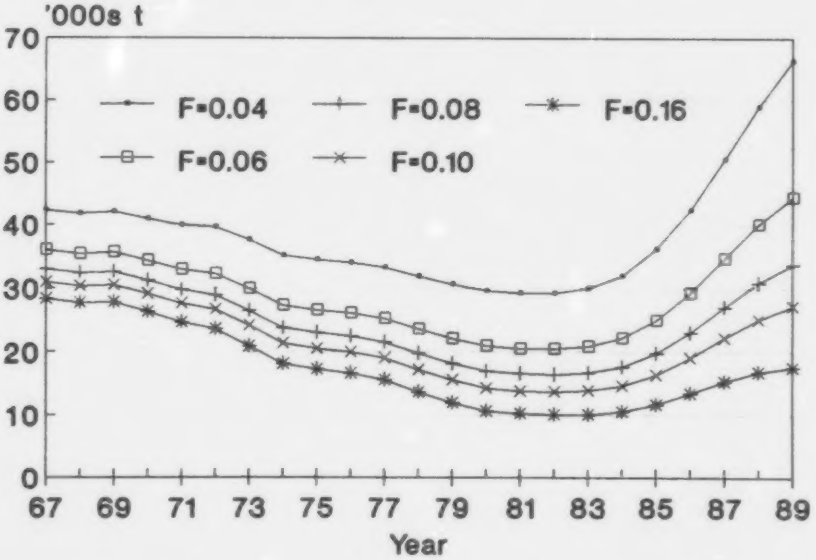

Fig. 10.5. Yellowtail rockfish, Q.C.Sd., available biomass trends with varying terminal F.

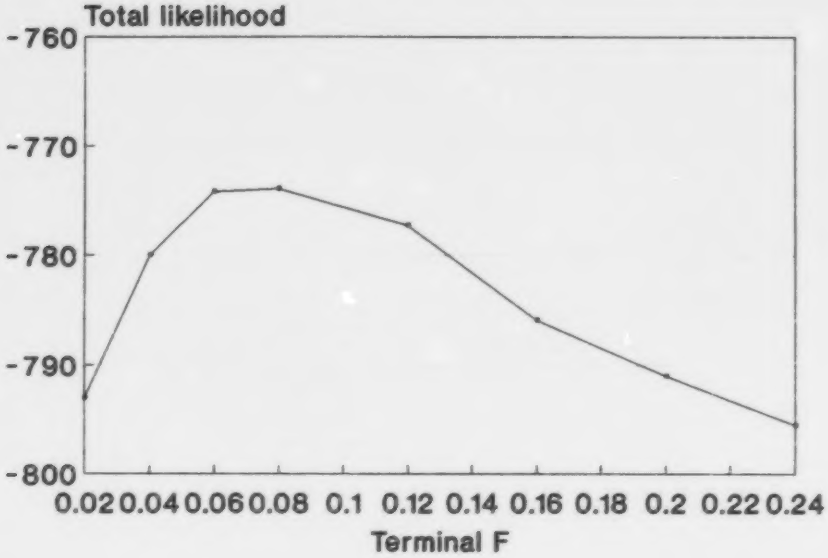

Fig. 10.6. Yellowtail rockfish, Q.C.Sd., total likelihood with effort emphasis = 1.0.

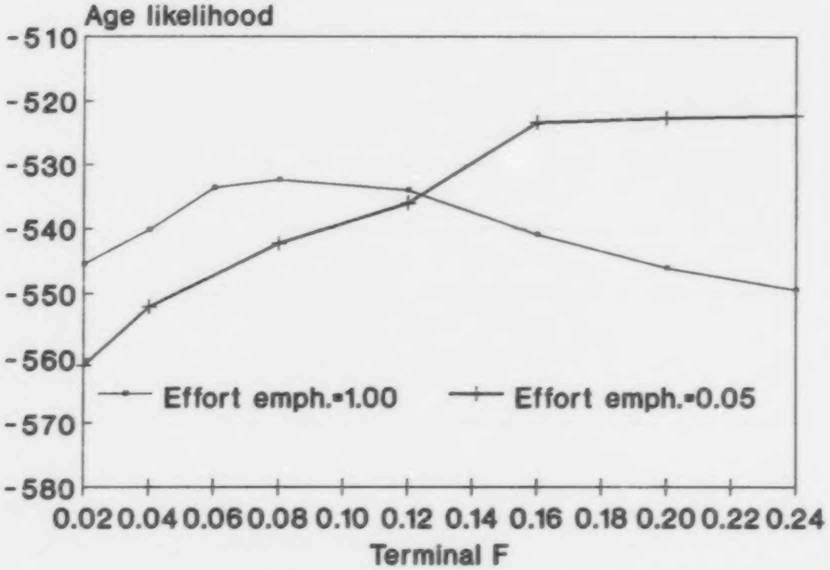

Fig. 10.7. Yellowtail rockfish, Q.C.Sd., age likelihood with effort emphasis = 1.00 or 0.05.

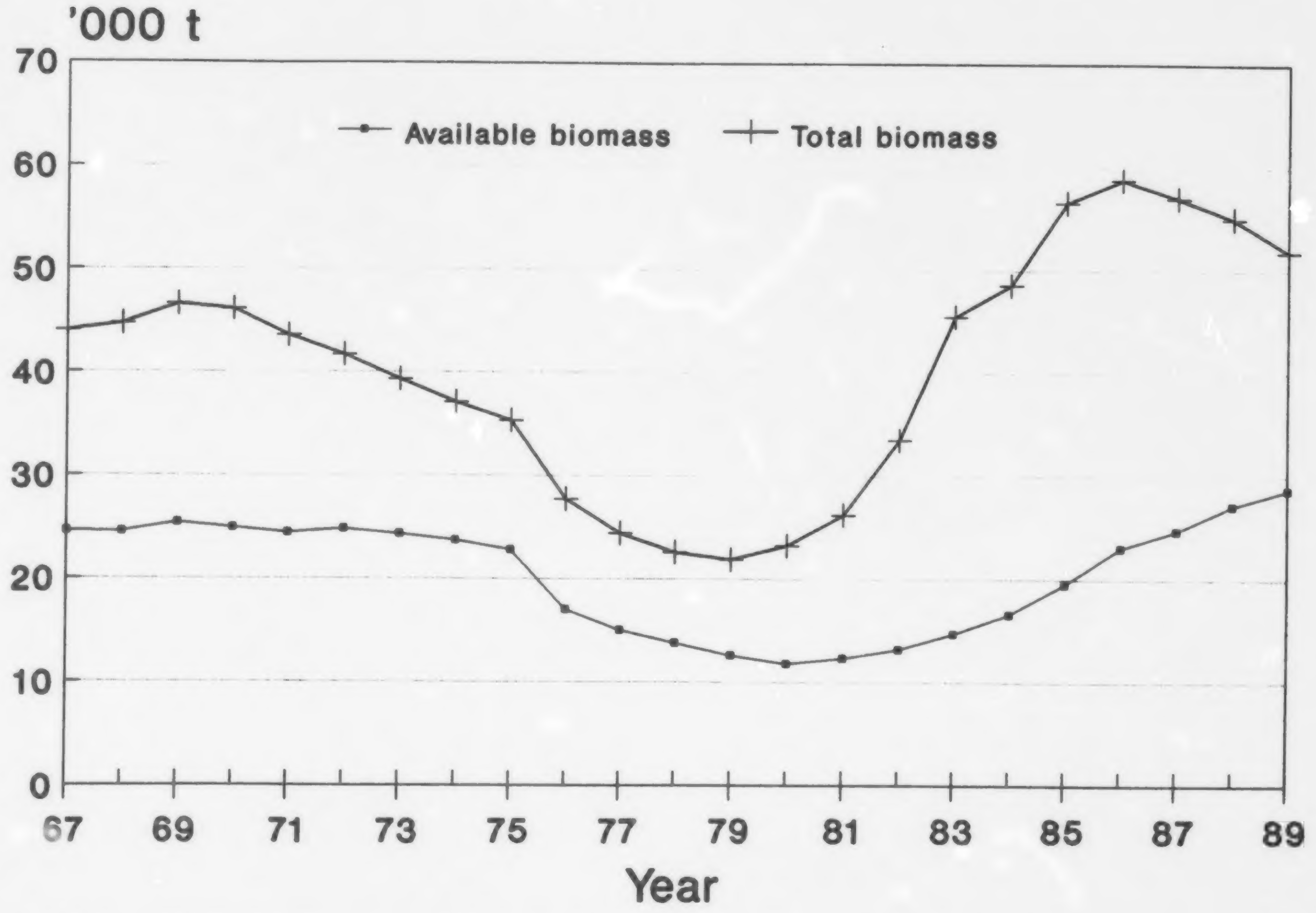

Fig. 10.8. Yellowtail rockfish, Nootka, B.C. available and total biomass trends with terminal F=0.08.

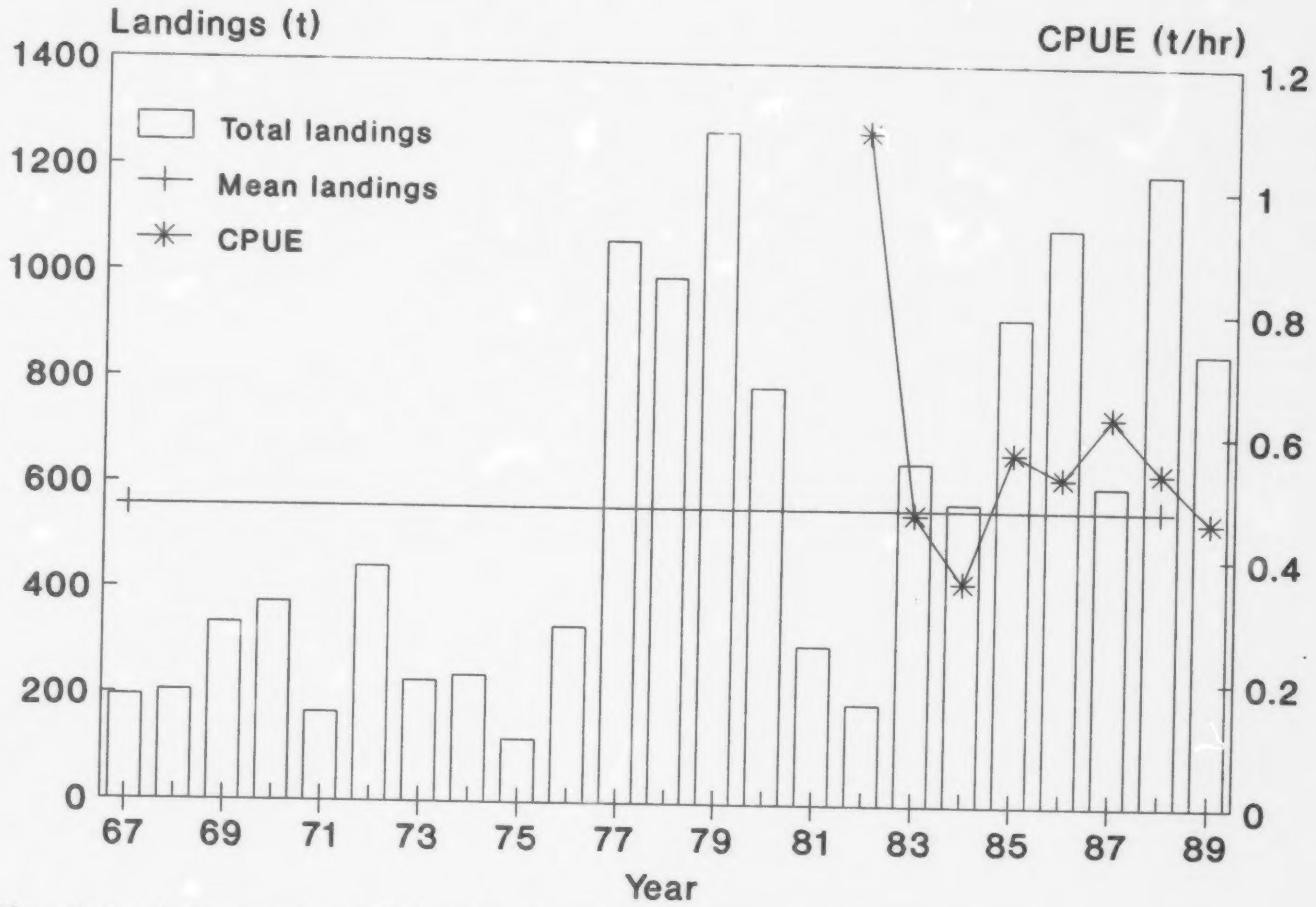

Fig. 10.9. Silvergray rockfish, Area 3C and 3D, landings and CPUE catch rate.

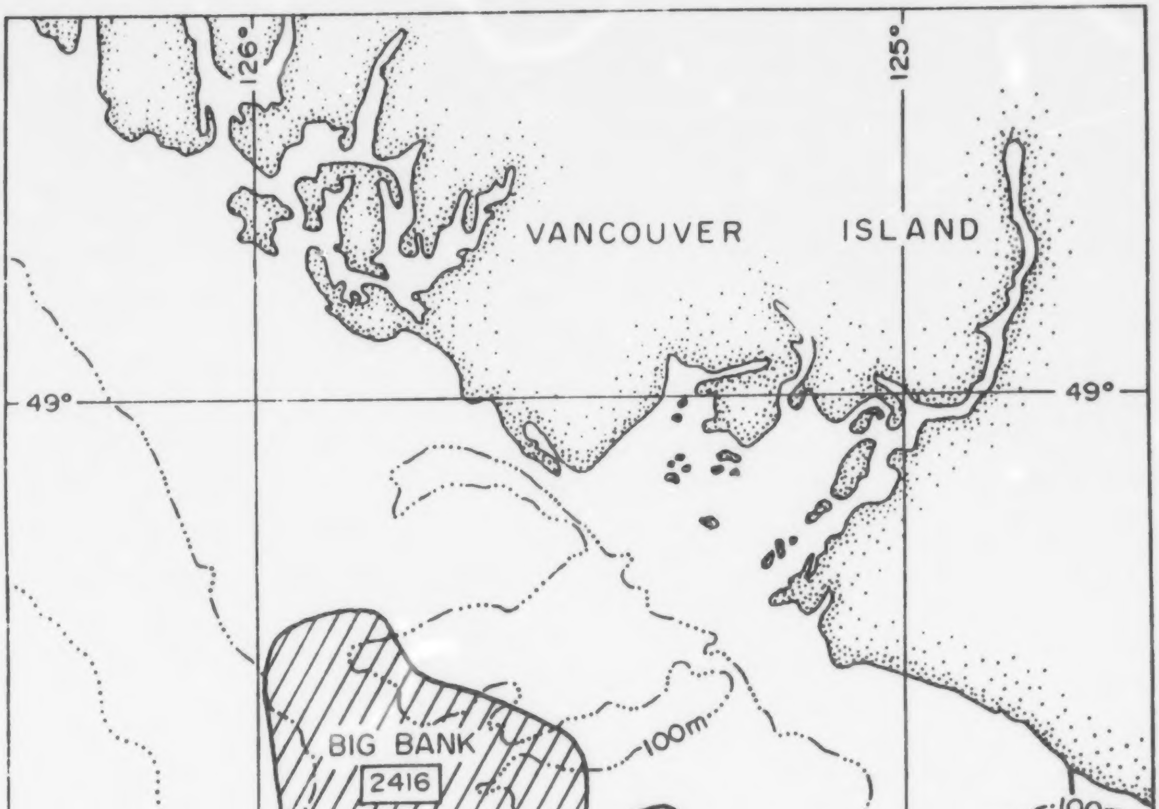
126°
125°
VANCOUVER ISLAND
49°
49°
BIG BANK
2416
100m
FINGER BANK
632
100m
100m
200m
200m
200m
OLLIE SPOT
3280
3C-CAN
3C-US
3B
7
4
3
1
1
2426
CAPE FLATTERY SPIT
2
3
2
4
48°
48°
126°
125°

Fig. 10.10. Yellowtail rockfish, tag recoveries of specimens tagged in Area 3C.

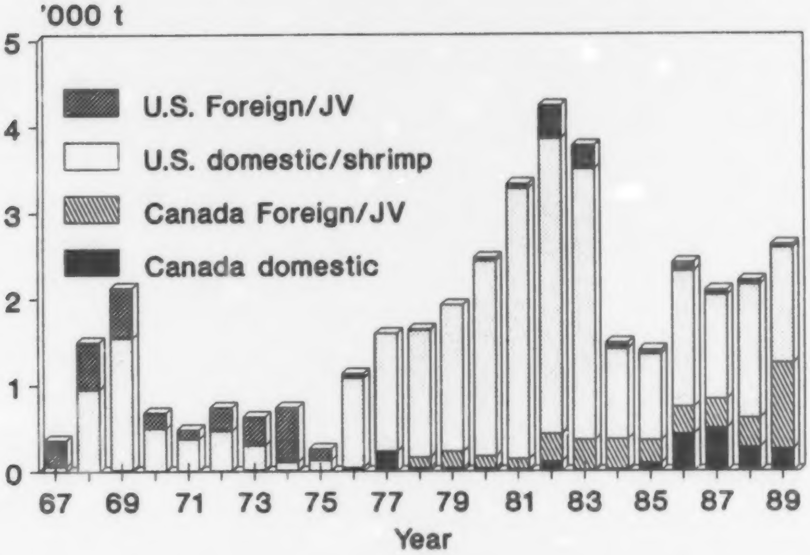

Fig. 10.11. Yellowtail rockfish landings by fishery from PMFC Areas 3C and 3B.

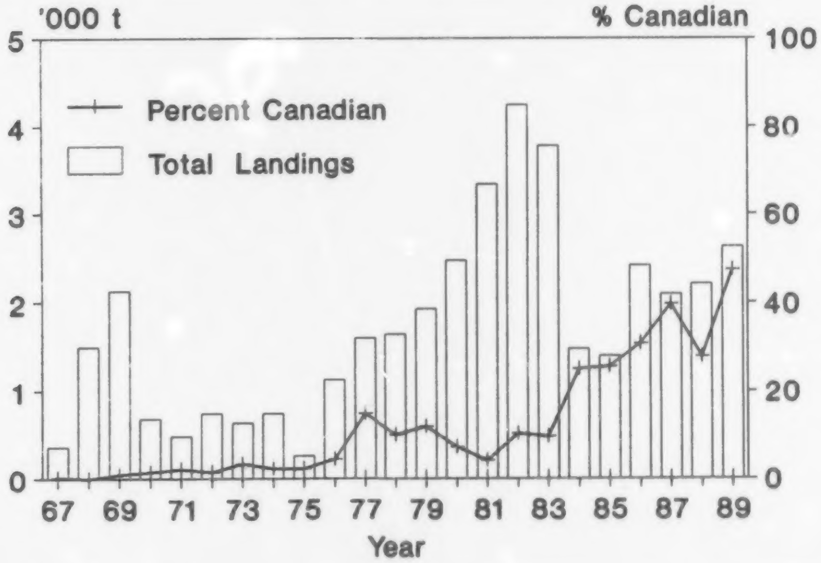

Fig. 10.12. Yellowtail rockfish landings and percent Canadian landings from PMFC Areas 3C and 3B.

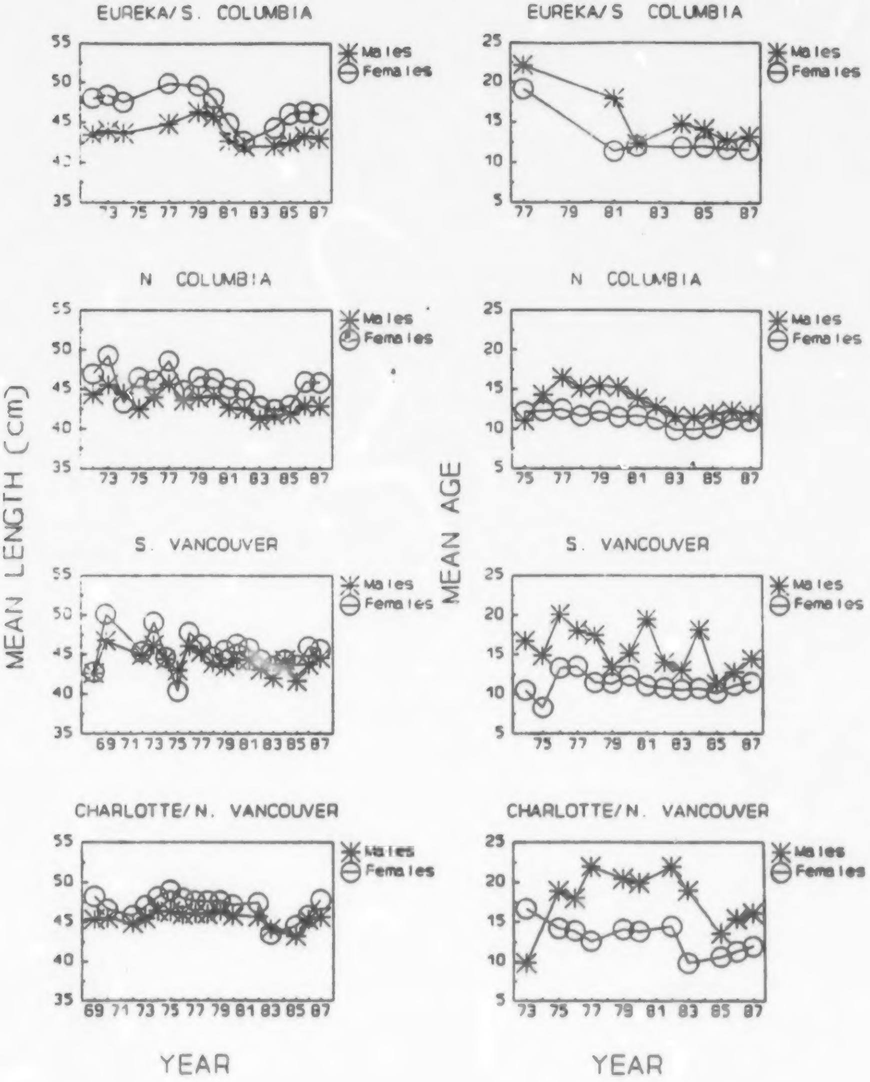

Fig. 10.13. Comparison of yellowtail rockfish mean length and mean age among four stocks, between 1969 and 1977 (from Tagart 1990).

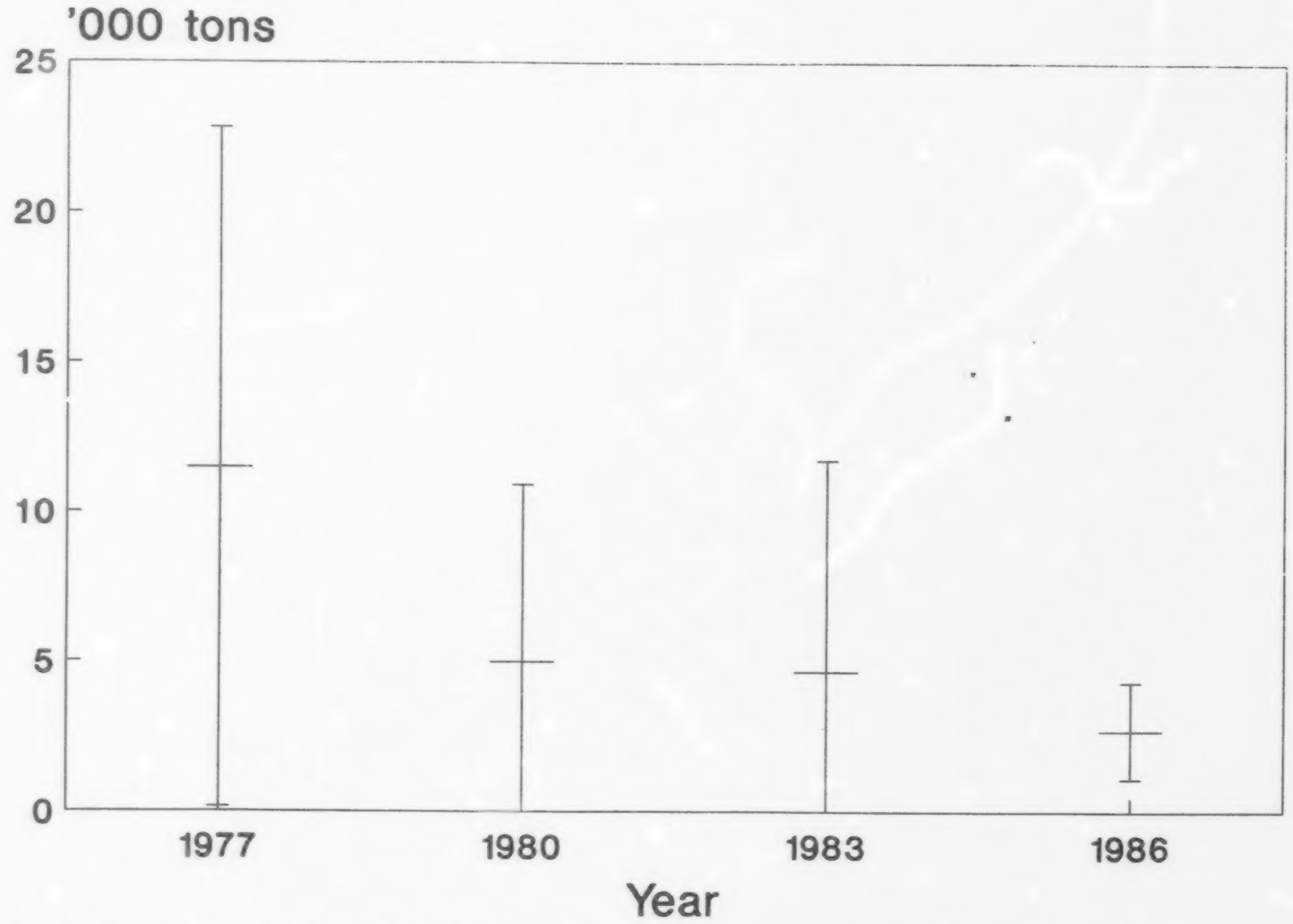

Fig. 10.14. Yellowtail rockfish biomass estimates from U.S. triennial survey, Areas 3C and 3B (90% confidence limits).

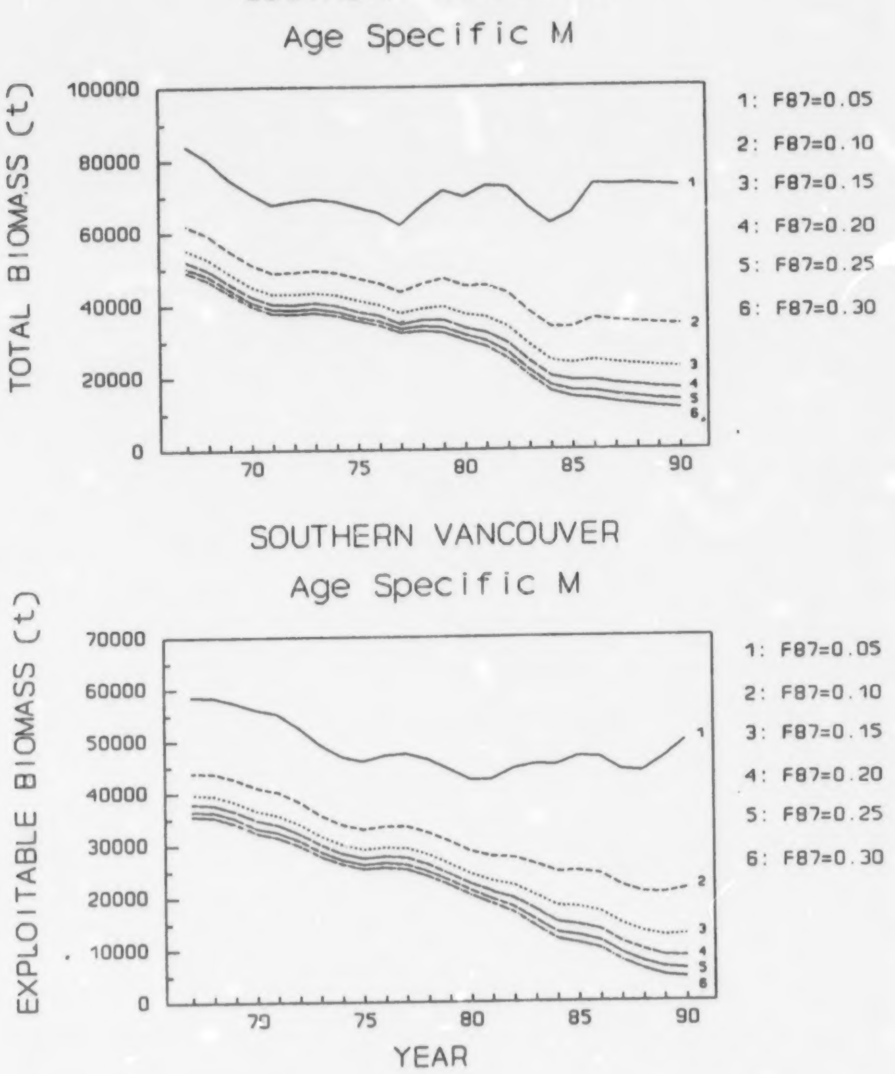

Fig. 10.15. Stock synthesis model estimates of beginning of the year yellowtail rockfish total and exploitable biomass for the Southern Vancouver area, assuming age specific natural mortality (from Tagart 1990).

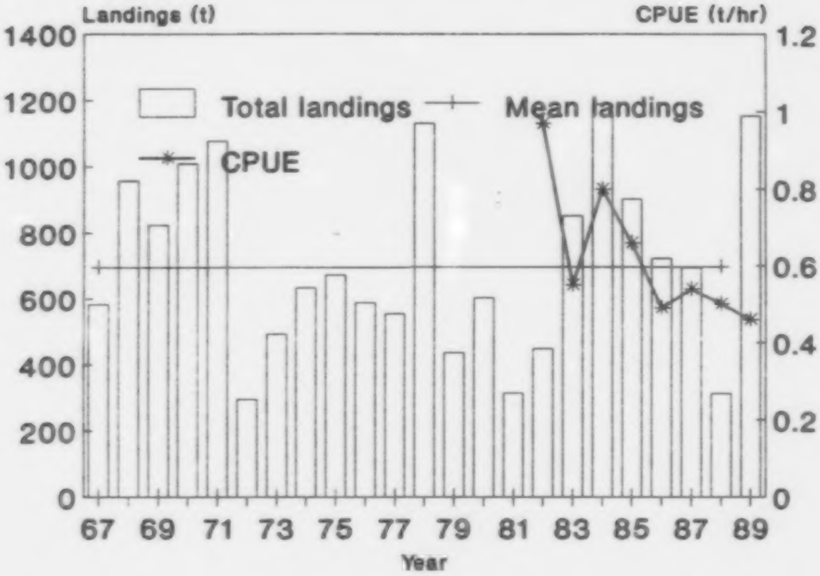

Fig. 10.16. Canary rockfish landings and CPUE in Areas 3C and 3D.

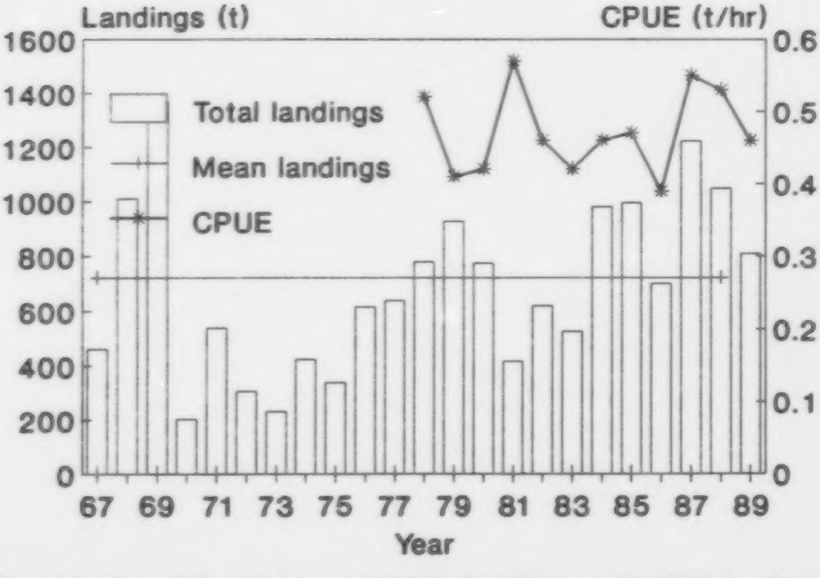

Fig. 10.17. Silvergray rockfish landings and CPUE in Areas 5A and 5B.

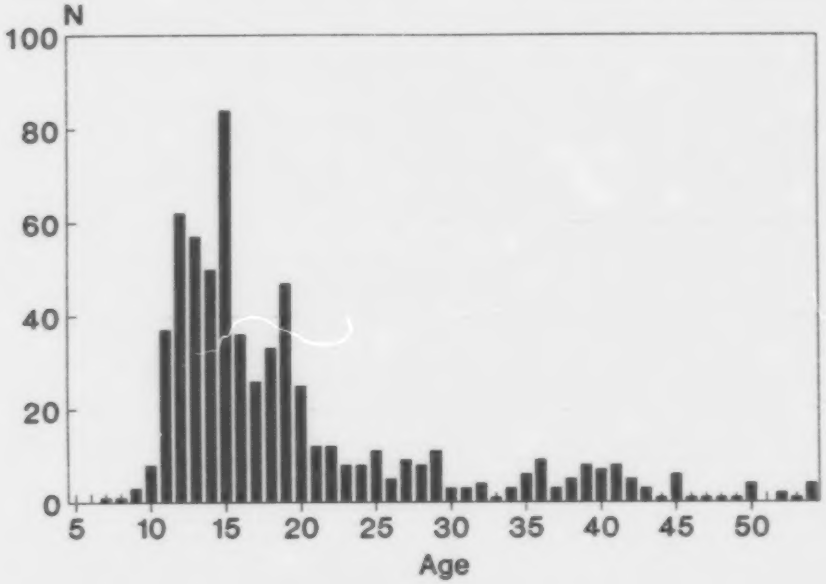

Fig. 10.18. Silvergray rockfish age composition for 1988 Q.C.Sd. samples, sexes combined.

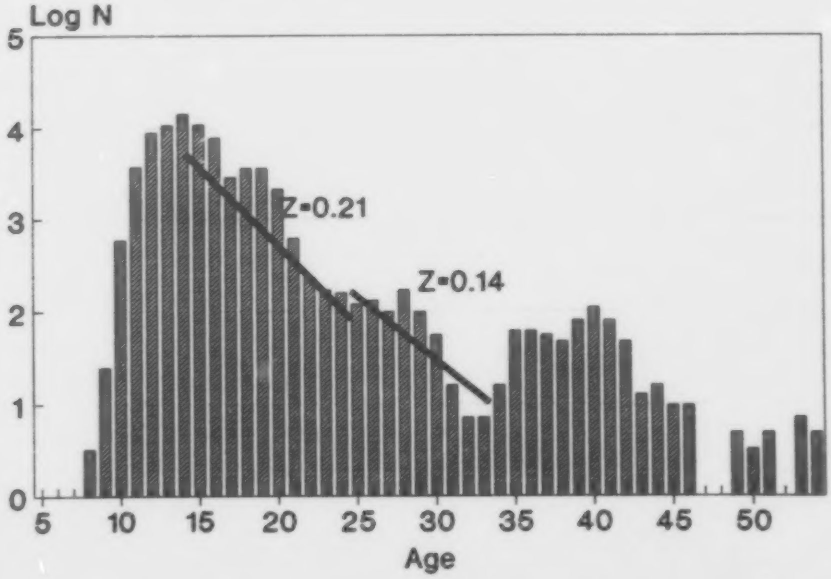

Fig. 10.19. Silvergray rockfish log age frequency for 1988 Q.C.Sd. samples, sexes combined.

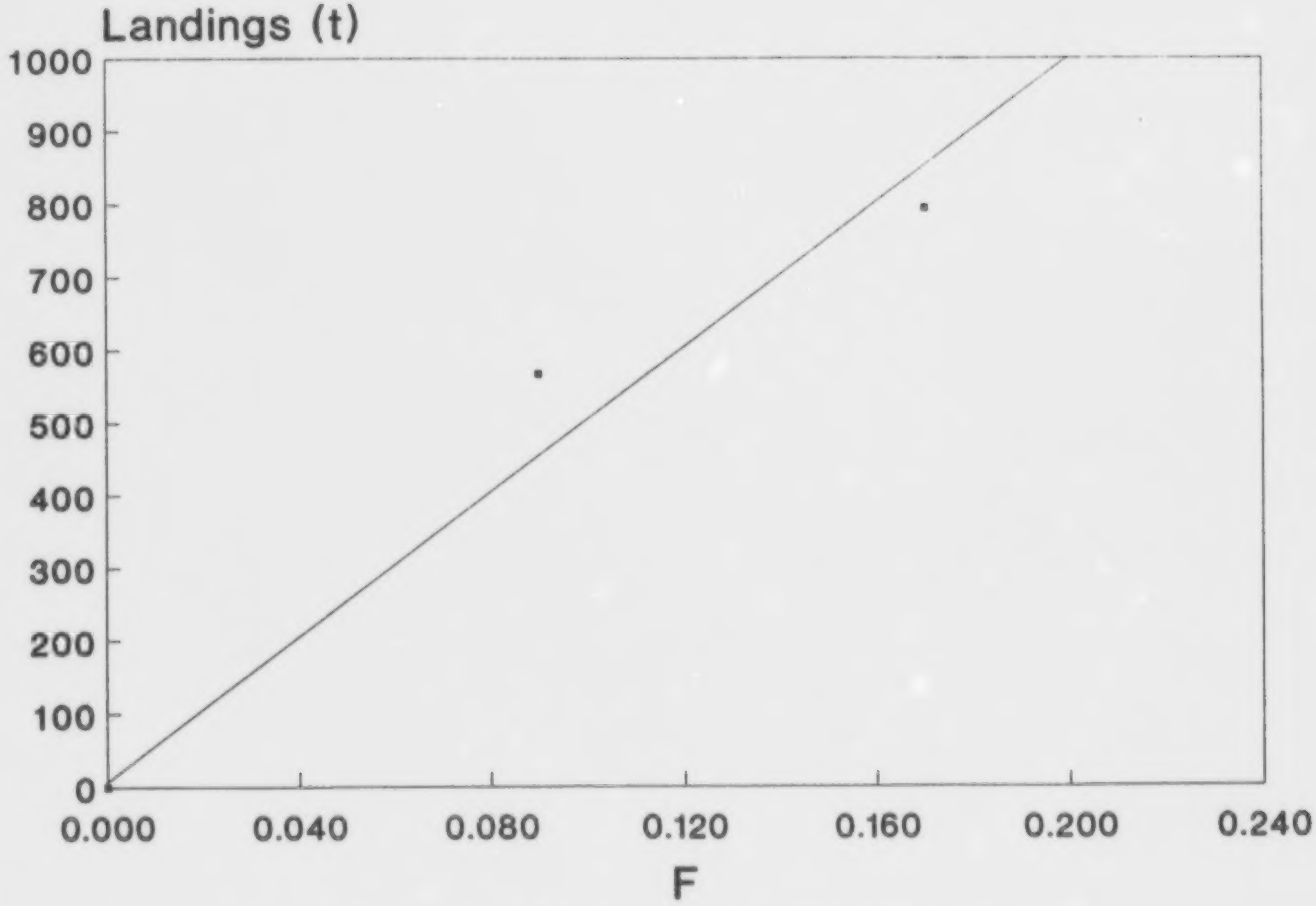

Fig. 10.20. Silvergray rockfish, Q.C.Sd., mean landings vs. F from catch curve.

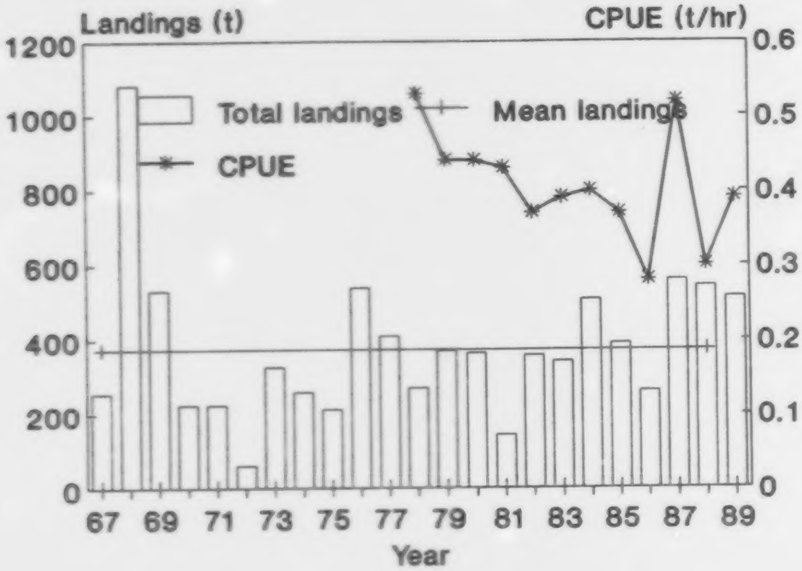

Fig. 10.21. Canary rockfish landings and CPUE in Areas 5A and 5B.

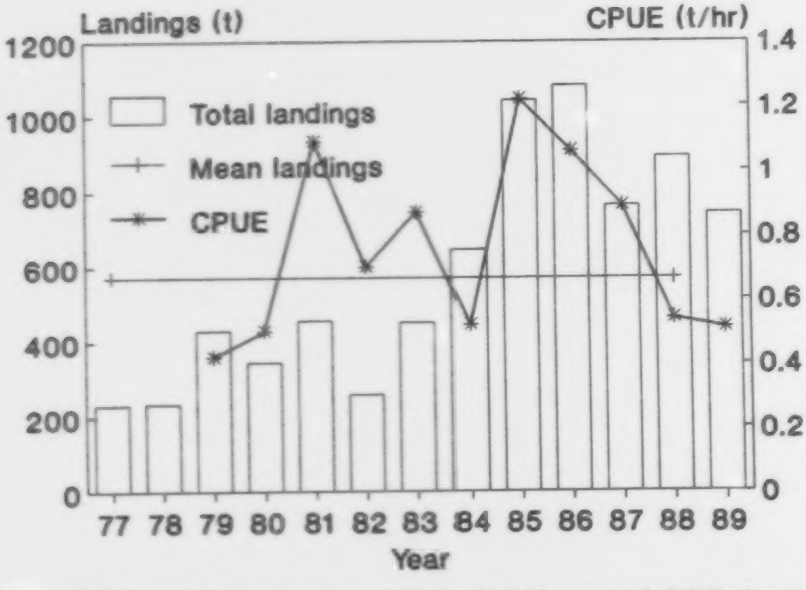

Fig. 10.22. Silvergray rockfish landings and CPUE from Areas 5C and 5D.

Appendix Table 10.1. Age specific parameter values used in template run of SSMOD for Queen Charlotte Sound Yellowtail rockfish.

Age	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20+
MORT(M)	0.059	constant														
MORT(F)	0.128	Constant														
WEIGHT(M)	0.566	0.686	0.802	0.916	1.018	1.111	1.193	1.269	1.340	1.452	1.500	1.539	1.569	1.609	1.630	1.630
WEIGHT(F)	0.514	0.668	0.827	0.978	1.122	1.254	1.376	1.486	1.584	1.671	1.748	1.816	1.875	1.927	1.972	2.011
PREC(M,BT)	0.015	0.039	0.100	0.232	0.450	0.690	0.859	0.943	0.979	0.992	0.997	0.999	1.000	1.000	1.000	1.000
PREC(F,BT)	0.012	0.032	0.083	0.198	0.402	0.646	0.832	0.931	0.974	0.991	0.997	0.999	1.000	1.000	1.000	1.000
PREC(M,MW)	0.006	0.014	0.029	0.062	0.124	0.236	0.402	0.595	0.765	0.882	0.949	0.983	1.000	1.000	1.000	1.000
PREC(F,MW)	0.003	0.008	0.022	0.058	0.147	0.326	0.575	0.792	0.915	0.969	0.990	0.997	1.000	1.000	1.000	1.000
PROP	0.078	0.121	0.182	0.266	0.370	0.488	0.607	0.715	0.803	0.868	0.915	0.946	0.966	0.979	0.987	0.992
MISAGE	0.250	0.263	0.276	0.289	0.302	0.315	0.328	0.341	0.354	0.367	0.380	0.393	0.406	0.419	0.432	0.445**

MORT(M) = instantaneous natural mortality for males
MORT(F) = " " " for females
WEIGHT(M) = weight of age (males)
WEIGHT(F) = " " (females)
PREC(M,BT) = partial recruitment factors at age (males: bottom trawl)
PREC(F,BT) = " " " " (females: bottom trawl)
PREC(M,MW) = " " " " (males: midwater trawl, from Nootka observations)
PREC(F,MW) = " " " " (females: midwater trawl, " " ")
PROP = proportion of females sexually mature.
MISAGE = proportion misaged (maximum = 0.5 at 25+)

11.0 INSHORE ROCKFISH (quillback, copper and yelloweye rockfish)

by C. M. Hand and L. J. Richards

11.1 Coastwide

Yield options are not proposed on a coastwide basis.

11.2 Strait of Georgia and vicinity (Area 4B)

11.2.1 The Fishery

The inshore rockfish fishery occurs throughout the Strait of Georgia and adjacent inside waters of Vancouver Island. Most of the commercial vessels use handline/troll or longline gear. The commercial fishery in its present form began to expand about 1977 (Fig. 11.1). At that time a market developed for live rockfish to supply restaurants and retail outlets, primarily in Vancouver's Chinatown. Rockfish have also been important to the sport fishery.

There were no restrictions on commercial catch prior to 1987. In 1987, a winter closure for Area 4B was implemented between Jan. 1 and Apr. 15. The closure was extended to Apr. 30 in 1988 and, in addition, Discovery Passage (subareas 13-2 to 13-9, 13-11 and 13-27) remained closed for the entire year. The winter closure was designed to reduce overall levels of effort. It coincided with a lingcod closure and covered the major period of parturition for the most common rockfish species. An incidental catch of yelloweye rockfish (S. *ruberrimus*) was permitted during this closed period, however, to accommodate a longline dogfish fishery. An experimental 75-t quota was placed on the area 12 rockfish catch in 1987 (excluding the yelloweye rockfish catch), but was not continued in 1988. The sport fishery has been restricted coastwide by a daily bag limit of eight rockfish since 1986.

Quillback rockfish (S. *maliger*) is the dominant species in the commercial handline/troll fishery and accounts for about 85% (by number) of the catch, based on commercial samples and the logbook program (Hand and Richards 1988). There are minor catches of several other species including copper rockfish (S. *caurinus*), yellowtail rockfish (S. *flavidus*), black rockfish (S. *melanops*), tiger rockfish (S. *nigrocinctus*), and yelloweye rockfish, as well as lingcod (*Ophiodon elongatus*) and kelp greenling (*Hexagrammos decagrammus*). Yelloweye rockfish is the dominant species in the commercial longline catch (Hand et al. 1990). Quillback rockfish, copper rockfish, yelloweye rockfish and unknown (or unidentified) rockfish account for, on average, 36%, 20%, 9% and 36% respectively, of the rockfish sport catch, based on the 1984-88 creel census (Shardlow and Collicutt 1989a-e).

11.2.2 Landing Statistics

Historically, most of the rockfish trawl catch was obtained from areas 18, 19 and 20 (Table 11.1). There were also significant trawl catches (over 10 t) in the 1950s and 1960s from area 14 and in the late 1960s and early 1970s from area 17. The area 4B annual trawl catch averaged 98 t between 1954-70. Since 1970, however, the trawl catch has decreased and is now at insignificant levels. The 1989 trawl catch is the lowest on record at 1.4 t. In general, the rockfish trawl catch has been incidental to other fisheries, in particular the Pacific cod fishery, although a yellowtail rockfish fishery has existed in area 20.

The rockfish catch by handline/troll and longline gear was less, historically, than the trawl catch, and averaged 65 t annually between 1954-76 (Table 11.2). The catch began to increase in 1976 and peaked at 527 t in 1986. The decrease in 1987 was probably due to the reduction in effort as a result of the winter closure and the area 12 quota. However, the 1988 and 1989 catches of 497 t and 452 t are again approaching the 1986 level. In particular, the area 12 catch increased by 69% between 1987-88 and again by 23% between 1988-89. Areas 12 and 13 accounted for 65% of the 1989 line catch.

The sport catch of rockfish, as estimated by the Strait of Georgia creel survey, averaged 122 t annually between 1982-89 (Table 11.3). Areas 12 and 20 were not covered by the survey, and the sport catch from these areas is not documented. The 1989 catch was above average at 140 t (assuming a weight of 0.7 kg/fish). This is 38% of the combined sport and commercial line catch from areas monitored by the creel survey.

Predation by sea mammals on rockfish may be significant. Harbour seal populations have been increasing at an annual rate of 2.5% since 1972 (Olesiuk et al. 1990a). Recent data suggest that rockfish account for 1.1% of the harbour seal diet which amounts to an estimated 112 t eaten during 1988 (Olesiuk et al. 1990b).

To provide a more meaningful analysis of commercial catch and CPUE, statistical areas within Area 4B are grouped by geographical area (Table 11.4). No information on stock delineation is available, although tagging experiments conducted in Puget Sound suggest that adult quillback and copper rockfish are fairly sedentary (Matthews 1990, Mathews and Barker 1983). CPUE is based on catch and effort by handline/troll and longline from total rockfish landings of at least 50 kg as reported on sales slips (Richards 1988). For the last 7 yr, catch and CPUE are also reported with the "red snapper" catch excluded. This is a market category that includes mainly yelloweye rockfish, but may also include canary rockfish (S. pinniger) and other "red" rockfish.

Richards and Schnute (1986) and Richards (1987) found CPUE for quillback rockfish to be strictly proportional to quillback rockfish densities in research surveys. Although the relationship between commercial fishery CPUE and rockfish abundance is not known, it is assumed that trends in CPUE are indicative of trends in abundance. However, the lack of a trend in CPUE does not necessarily indicate a uniform stock size. Due to rockfish behavior and the nature of the fishery, stock collapse is possible during periods of apparently high CPUE. For example, CPUE could remain high as isolated reefs are progressively exploited.

Landings and CPUE in area 4B have been increasing since the inception of the line fishery in 1977 (Fig. 11.2). Peak values for both commercial catch and CPUE occurred in 1986. After 1986, CPUE tended to decrease. The 1989 value of CPUE is the lowest since 1985.

Trends in catch, CPUE, and effort for area 12 are shown in Table 11.4a. The area 12 fishery developed rapidly in 1985 with a catch more than triple that of the previous year. The 1989 catch of 228 t is the highest on record. Similar catches were observed in area 13 in 1983-84 and could not be sustained. Values of total rockfish CPUE in area 12 have remained relatively constant since the development of the fishery, with the exception of the abnormally high value in 1986. The series that excludes the red snapper catch shows a similar trend until 1989 when the CPUE value decreased.

In area 13 (Table 11.4b), total rockfish CPUE averaged 58.4 kg/d between 1977-83 during the build-up of the fishery. The maximum catch of 200 t occurred in 1983. Between 1984-87, CPUE declined significantly to an average of 46.1 kg/d (t-test, $p<0.01$), coincident with the decrease in catch. In 1988, CPUE apparently increased again to near pre-1983 levels. This may have been a result of the closure of Discovery Passage which forced vessels to either leave the fishery or to move to less accessible and therefore less exploited regions. CPUE decreased again to 46.3 kg/d in 1989. Fewer vessels reported qualified landings in area 13 in 1989 than in any other year and effort continued to decline.

The fishery in Sechelt (areas 15-16, Table 11.4c) appears to be on the decline. Landings, CPUE and the number of vessels have all decreased since 1986. There are no obvious long-term trends in catch or CPUE in the Gulf Islands (areas 14, 17-19, Table 11.4d).

11.2.3 General Biological Information

Biological samples have been collected from the commercial fishery since 1984 (Table 11.5). In area 12, there are no consistent trends in mean size of quillback rockfish sampled over the course of the fishery. The length distributions of the commercial samples may in part be determined by market preferences; larger fish ("hogs") have a lower value. However, mean lengths obtained from commercial samples tend to be larger than the mean lengths of 34-35 cm from research surveys in 1986-88 (Richards and Cass 1987, Richards and Hand 1987, Richards et al. 1988) conducted over moderate depths (41-70 m). Based on two samples aged to date (1986 and 1988), the mean age in the commercial catch is 25 yr (n=404) with a range in age of 5-60 yr.

In area 13, mean size of quillback rockfish decreased from 33 to 29 cm between 1984-87. The 1986-87 samples that demonstrate the major decrease were obtained from Discovery Passage. Mean lengths were similar to the lengths of 30-31 cm obtained from research fishing at moderate depths (41-70 m) in Discovery Passage between 1987-88 (Richards and Hand 1987, Richards et al. 1988). With the closure of Discovery Passage in 1988, fishing effort shifted to other areas. Mean lengths (32-33 cm) were higher from the 1988-89 commercial samples, collected from east of Quadra Island. However, no difference was found in mean size of quillback rockfish caught deeper than 40 m in Discovery Passage or near Stuart Island during the 1988 research survey. Smaller fish were caught in Discovery Passage at depths less than 40 m (Richards et al. 1988).

Only four commercial quillback rockfish samples have been collected from area 17, one from area 18, and none from the remaining areas of the Strait of Georgia. Based on the commercial samples (Table 11.5) and the research program in area 16 (Richards and Cass 1987) and area 17 (Hand and Richards 1987, 1989), the size distribution of quillback rockfish landed in these areas appears to be intermediate between the distributions in areas 12 and 13.

The proportion of the population surviving each year, and hence total mortality rates, were estimated from age-frequency data (Richards and Hand 1990). Separate analyses were conducted for commercial and research sample data from areas 12 and 13 for both quillback and copper rockfish. The research data were collected during surveys (Richards and Cass 1987, Richards and Hand 1988). Estimates of survival and mortality were remarkably similar for the two area 12 samples. In contrast, the estimate of survival is significantly lower ($p<0.05$) for the area 13 samples, and survival is significantly lower for copper rockfish.

To examine among-areas differences in growth of quillback rockfish, the von Bertalanffy growth model

$$y = L_{\infty}(1-e^{-k(t-t_0)})$$

was applied to quillback rockfish length-at-age data. Similar parameter estimates were obtained for samples from areas 12 and 13 (Table 11.7). Hence, quillback rockfish populations in areas

12 and 13 have similar growth rates. Size at maturity for quillback rockfish from area 13 is 292 mm with a 95% confidence interval of 285-298 mm (Schnute and Richards 1990). In contrast, copper rockfish from area 13 grow at a faster rate and attain a smaller maximum size.

Two samples have been collected from the yelloweye longline fishery in area 17 and one sample collected from area 16. Yelloweye rockfish from area 17 had a mean length (SE) of 481 (5) mm and were considerably smaller than yelloweye rockfish obtained from other regions of the British Columbia coast (Table 11.5). Yelloweye from the one sample from area 16 were considerably larger at 609 (5) mm. Although ageing techniques have not been validated for this species, the mean age of both samples combined is tentatively 33 yr. Length at 50% maturity for female yelloweye rockfish is approximately 440 mm.

11.2.4 Condition of the stock

Based on the record of rockfish fisheries in other areas of the coast, and the early indicators of stock decline in the Strait of Georgia and vicinity, this fishery cannot be maintained at current levels of exploitation. Furthermore, the fishery will likely collapse before warning signs become evident. If over-exploitation does occur, the consequences for rehabilitation are long-term (at least 10 yr for quillback rockfish).

It is not yet clear to what extent the drop in quillback/copper rockfish CPUE in area 12 in 1989 signals a downward trend in stock abundance. The 1989 catch in area 12 was the highest on record and similar to a level shown to be non-sustainable in area 13. Approximately 50% of the landings from area 12 are obtained from a region with less than 2% of the fishable shoreline, a situation analogous to the former Discovery Passage fishery (area 13).

Quillback rockfish stocks in area 13 remain in relatively poor condition. These stocks were depleted by the fishery between 1982-1984. Although CPUE apparently increased in 1988, the 1989 index is again low. Mean fish sizes measured in 1988 and 1989 are considerably smaller than those measured for area 12, although growth rates are similar for the two areas (Table 11.7). Furthermore, quillback rockfish mortality rates are significantly higher in area 13 (Table 11.6). The fishery in Sechelt also appears to be on the decline with decreases in catch, CPUE, effort and the number of participating vessels. The condition of stocks in the Gulf Islands is less certain, as there have been few biological samples and no clear trends in catch or CPUE.

Yelloweye rockfish account for an increasing proportion of the Area 4B rockfish catch, and effort on yelloweye rockfish reached relatively high levels in 1988 and 1989 (Table 11.8).

Based on the experience of the Alaska yelloweye rockfish fishery, it is unlikely that the yelloweye rockfish stock can sustain increased fishing pressure. These stocks already show signs of heavy exploitation, as the mean size of yelloweye rockfish from area 17 is smaller than that from other areas of the coast.

11.2.5 Yield Options

It is recommended that the Area 4B sport and commercial rockfish catch (excluding the yelloweye catch) not exceed the sustainable level of 400 t for 1991. This yield option differs from options presented in previous years in that the sport fishery catch is included explicitly. The sustainable level is based on historical catch and determined from the sum of the yields by area - 100 t for area 12, 75 t for area 13, and 225 t for areas 14-20, 28, and 29. If area 4B is managed by a single quota, then catches above the sustainable yield from a particular area will lead to reduced future yields. The commercial line and sport catch have exceeded 400 t each year since 1982 (Fig. 11.2) and continued high catches will severely deplete these stocks.

It is recommended that the Area 4B yelloweye catch not exceed the sustainable level of 50 t for 1991. This level is based on historical catches. Higher average catches between 1983-87 led to the apparent stock depletion.

11.3. West Coast Vancouver Island (Area 3C-D)

11.3.1 Landing Statistics

The rockfish line catch off the west coast of Vancouver Island has increased dramatically since 1985, and has exceeded landings from other areas of the coast since 1986 (Fig 11.1). The handline/troll catch increased in both 1986 and 1987, but decreased in 1988 and 1989 (Table 11.9). Most of the catch was obtained from areas 11, 23, 24 and 27. (As the statistics do not differentiate between inshore and offshore areas, the reference to an inshore area includes the corresponding offshore areas.) The increase in the rockfish longline fishery has been more sudden. Longline catch jumped from 72 to 420 t between 1985-86, remained near that level in 1987-88 and increased 45% to 522 t in 1989 (Table 11.10). Although the rockfish longline fishery extends along the west coast of Vancouver Island, the largest catches were recorded from areas 11 and 27. The "red snapper" (mainly yelloweye rockfish) component of the west coast line catch has increased from 34% of the total in 1983 to 70% in 1989 (Table 11.8).

Unlike the Area 4B fishery, much of the rockfish line catch off the west coast of Vancouver Island occurs incidentally to other line fisheries, for example, halibut, dogfish, and lingcod fisheries. A directed rockfish catch was conservatively defined as a catch in which rockfish comprised at least 50% of the landed weight. By this definition, only 57% of the 1988 west coast catch occurred in a directed fishery. The comparable value for Area 4B is 91%. In addition, there are undocumented discards of yelloweye rockfish caught in the halibut fishery. The rate of incidence of yelloweye rockfish in the halibut catch is conservatively estimated at 5% by number, most or all of which is discarded at sea (B. Leaman, PBS, pers. comm.). The present halibut fishery in B.C. is approximately 900,000 fish with about 10% taken off the west coast of Vancouver Island. This would generate a mortality of about 20 t of yelloweye rockfish, based on the weight of yelloweye rockfish in commercial samples.

Yelloweye rockfish CPUE is based on catch and effort by handline/troll and longline from 'red snapper' landings of at least 50 kg as reported on sales slips. Similarly, other rockfish CPUE is based on line landings of rockfish of at least 50 kg, excluding the red snapper catch. Yelloweye CPUE has increased steadily since the initial expansion of the fishery, except for the drop in 1987, and effort has remained high since 1986 (Table 11.8). These are indicators of a developing fishery.

11.3.2 General Biological Information

No samples from the commercial handline fishery have been collected from this area. Five samples of yelloweye rockfish were collected from the commercial longline fishery between 1988 and 1990. Mean fish sizes were intermediate between mean sizes in samples from the Strait of Georgia and the Queen Charlotte Islands (Table 11.5).

11.3.3 Yield Options

There is little information on which to base yield options. However, given the experience of other rockfish fisheries, stocks may be rapidly depleted without strong biological indications of the impending collapse. It is recommended that the rockfish line catch (areas 11, 21-27, 111, and 121-127) be restricted to the sustainable level of 400 t for a 5-yr period to allow a review of appropriate yield options. This level is equivalent to the sustainable yield for Area 4B. Catches have exceeded 400 t since 1986 and continued catches at the 1989 level may led to stock depletions.

11.4. North Coast (Area 5A-E)

11.4.1 Landing Statistics

The rockfish line catch from the north coast has increased dramatically since 1984 and has exceeded the Area 4B catch since 1987 (Fig. 11.1). The handline/troll fishery has traditionally been small on the north coast (Table 11.9). Catch gradually increased between 1984-87, and then more than doubled between 1987-88, primarily due to the expansion of the fishery into the Bella Bella region (area 7). This reflects a shift in effort associated with a winter closure in the Strait of Georgia. There were no restrictions on the commercial fishery prior to 1990. In 1990, most of area 7 was closed to commercial fishing.

The rockfish longline fishery has also been increasing since 1984 (Table 11.10). The 1989 catch was the highest on record at 442 t. Most of the catch was obtained near the Queen Charlotte Islands (areas 1-2). Undocumented discards of yelloweye rockfish from the halibut fishery are conservatively estimated at 160 t for the north coast (see Section 11.3.1).

Similar to the west coast, rockfish line catches off the north coast occur incidentally to other line fisheries. A directed rockfish catch was conservatively defined as a catch in which rockfish comprised at least 50% of the landed weight. By this definition, 54% of the north coast catch occurred in a directed fishery in 1988.

To further examine trends in catch and CPUE, the north coast was divided into three regions, the Queen Charlotte Islands (areas 1-2), the North Coast (areas 3-5) and the Central Coast (areas 6-10). Red snapper CPUE is based on catch and effort by handline/troll and longline from red snapper landings of at least 50 kg as reported on sales slips. Similarly, other rockfish CPUE is based on line landings of rockfish of at least 50 kg, excluding the red snapper catch. A longline fishery for red snapper appears to be developing in the Queen Charlotte Islands, where catch and CPUE have been generally increasing since about 1985 (Table 11.8). Catch in the North Coast is low and there are no clear trends in CPUE. Catch and CPUE from the Central Coast yelloweye fishery are both increasing, as is typical of the developmental stage of a fishery. There was a decrease in catch and CPUE in the quillback/copper rockfish fishery, probably as a result of the closure in area 7.

11.4.2 General Biological Information

Two rockfish samples have been collected from the commercial handline fishery in area 7. Quillback rockfish accounted for 89% of the number of fish in the samples, and there were small numbers of copper rockfish, yelloweye rockfish and kelp greenling. The quillback rockfish had a mean size comparable to those sampled from area 13 (Table 11.5). Quillback rockfish otoliths collected from the 1988 sample only have been aged to date. Survival rates for quillback rockfish sampled from area 7 are not significantly different from those obtained for fish sampled from area 12 (Table 11.6). However, quillback rockfish from area 7 grow at a significantly slower rate and attain a smaller maximum size than do fish from areas 12 and 13 ($p<0.001$) (Table 11.7).

Four yelloweye rockfish samples were collected from the commercial longline fishery along the west coast of the Queen

Charlotte Islands (area 2). Mean fish sizes were larger than for samples collected from the Strait of Georgia and the West Coast (Table 11.5). Two samples were collected from the Central Coast (area 6 and 7). Mean fish sizes, 566 and 552 mm, were comparable to samples collected from the West Coast.

11.4.3 Yield Options

There is little information on which to base yield options. However, given the experience of other rockfish fisheries, stocks may be rapidly depleted without strong biological indications of the impending collapse. Sustainable yields determined from the 1989 catch are 300 t for the Queen Charlotte Islands (areas 1, 2, 101, 102, and 142), 100 t for the North Coast (areas 3-5, 103-105), and 200 t for the Central Coast (areas 6-10, 106-110, and 130). It is recommended that catches be maintained at the sustainable levels for a 5-yr period to evaluate these yields.

Table 11.1. Rockfish trawl catch (t) for Area 4B by statistical area, from Groundfish data files, 1954-89.

	Statistical Area											
Year	12	13	14	15	16	17	18	19	20	28	29	Area 4B Total
1954	5.0	0.3	29.5	0.0	0.0	7.7	11.4	0.7	60.7	0.0	4.8	120.1
1955	1.5	0.1	12.1	0.0	0.1	8.4	87.1	1.0	19.5	0.0	0.8	130.5
1956	5.6	0.6	15.3	0.0	0.0	9.1	4.3	17.2	18.1	0.0	1.4	71.6
1957	0.9	0.3	14.5	0.2	0.0	8.5	4.5	0.5	1.2	0.1	2.6	33.3
1958	1.2	0.8	8.0	0.0	0.0	9.9	2.0	3.1	27.2	0.0	1.2	53.3
1959	1.0	0.9	6.2	0.0	0.0	8.3	16.1	48.3	77.5	0.0	0.7	159.0
1960	0.8	0.3	7.2	0.0	0.1	6.1	8.3	7.6	144.8	0.0	0.7	175.7
1961	1.6	0.1	11.1	0.2	0.3	7.7	15.5	6.0	61.0	0.0	0.8	104.1
1962	2.4	0.8	9.0	0.0	0.5	9.1	12.6	0.3	56.9	0.0	1.0	92.7
1963	0.1	1.5	10.5	0.0	0.0	7.4	14.6	0.9	17.3	0.0	0.4	52.8
1964	0.3	5.0	5.7	0.0	0.0	8.9	20.1	4.5	71.4	0.0	1.2	117.1
1965	0.5	1.1	8.3	0.0	0.0	2.1	9.6	4.0	38.6	0.0	1.0	65.3
1966	2.2	0.0	7.5	0.0	0.0	1.7	7.8	0.8	118.8	0.0	0.0	138.8
1967	2.3	1.2	4.5	0.0	0.0	2.9	5.2	0.7	31.8	0.0	0.1	48.9
1968	1.4	0.0	6.3	0.0	0.0	21.7	4.2	0.9	64.4	0.0	0.1	98.9
1969	0.8	1.2	9.1	0.0	0.0	4.4	5.4	2.4	75.5	0.0	0.3	99.0
1970	0.0	0.0	5.9	0.0	0.0	12.5	7.8	0.1	75.9	0.0	0.2	102.4
1971	0.1	0.1	6.4	0.0	0.0	9.1	7.0	0.4	10.5	0.0	0.6	34.2
1972	0.0	0.0	6.1	0.0	0.0	7.4	2.9	0.1	29.1	0.0	0.0	45.6
1973	0.5	1.9	3.1	0.0	0.0	12.1	2.9	0.0	3.5	0.0	0.1	24.0
1974	0.0	0.2	5.3	0.0	0.0	5.6	5.7	0.1	4.1	0.0	0.6	21.7
1975	0.1	1.8	4.0	0.0	0.0	2.3	7.6	2.4	10.9	0.0	0.0	29.1
1976	0.2	1.0	3.3	0.0	0.0	2.0	9.1	1.1	14.3	0.0	0.0	31.1
1977	1.2	0.8	5.2	0.0	0.0	2.6	7.9	2.0	10.5	0.0	0.0	30.1
1978	9.8	0.4	5.6	0.0	0.0	1.7	12.3	5.7	16.6	0.0	0.1	52.0
1979	0.4	0.0	3.8	0.0	0.0	3.6	15.7	17.5	82.9	0.0	0.4	124.2
1980	0.1	0.1	1.2	0.0	0.0	5.2	6.4	6.1	20.7	0.0	0.1	39.8
1981	0.6	0.0	1.8	0.0	0.0	2.6	11.0	15.8	17.9	0.0	1.5	51.1
1982	0.0	0.1	2.9	0.0	0.1	5.2	9.7	11.5	19.2	0.0	0.2	48.7
1983	2.7	0.1	0.9	0.0	0.0	3.5	11.1	4.2	4.8	0.0	0.1	27.4
1984	0.1	0.0	1.1	0.0	0.0	1.8	15.4	7.7	12.3	0.0	0.4	38.8
1985	0.2	0.0	0.9	0.0	0.0	2.2	6.6	6.8	8.5	0.0	0.1	25.2
1986	0.0	0.1	1.1	0.0	0.0	4.3	5.0	1.4	33.8	0.0	0.0	45.6
1987	0.0	0.1	2.2	0.0	0.1	3.5	1.9	2.4	4.6	0.0	0.0	14.8
1988	0.0	0.0	0.3	0.0	0.0	0.8	0.8	0.8	2.7	0.0	0.1	4.7
1989	0.1	0.0	0.4	0.0	0.0	0.5	0.4	0.0	0.0	0.0	0.0	1.4

Table 11.2. Rockfish handline/troll and longline catch (t) for Area 4B by statistical area, from British Columbia catch statistics Annual Reports, 1954-89.

	Statistical Area											
Year	12	13	14	15	16	17	18	19	20	28	29	Area 4B Total
1954	6.3	6.8	0.8	0.6	6.8	15.1	6.1	0.0	0.0	0.4	0.0	43.0
1955	6.3	6.8	0.8	0.6	6.8	15.1	6.1	0.0	0.0	0.4	0.0	43.0
1956	6.8	2.0	0.2	1.0	5.0	19.0	5.5	0.1	0.1	0.0	0.2	39.9
1957	5.7	6.1	2.5	2.8	14.5	26.0	7.0	6.5	0.0	0.1	1.1	72.4
1958	8.0	10.8	9.8	6.0	15.4	29.3	15.8	6.3	3.2	0.0	2.0	106.6
1959	13.2	16.4	9.3	10.7	10.9	36.4	4.0	3.9	0.5	0.1	0.7	106.1
1960	10.1	20.1	4.8	11.8	11.2	19.8	3.5	3.2	0.9	0.4	0.1	86.0
1961	10.4	16.9	6.5	2.7	4.9	16.2	3.2	1.4	0.6	0.1	1.5	64.5
1962	52.8	15.1	4.7	5.8	3.1	19.7	2.4	2.5	0.6	0.2	0.5	107.5
1963	39.1	7.8	3.7	1.6	6.2	16.4	2.8	0.9	0.2	0.0	0.2	78.8
1964	11.1	4.6	2.1	0.9	12.8	8.8	2.8	1.1	0.7	0.0	0.1	45.1
1965	10.2	3.5	2.1	0.1	10.3	9.3	3.3	0.4	0.1	0.0	0.3	39.6
1966	4.2	3.6	3.8	0.5	13.0	4.1	4.1	0.2	0.1	0.1	0.0	33.8
1967	9.9	7.6	5.9	3.4	16.7	6.3	1.9	0.1	0.1	0.0	0.0	51.9
1968	11.8	8.2	5.0	1.0	19.0	10.3	1.4	0.2	0.1	0.0	0.0	57.0
1969	25.3	12.0	3.8	3.5	16.6	8.8	4.2	0.3	0.9	0.0	0.1	75.6
1970	23.8	16.9	4.0	5.0	9.8	16.1	1.5	0.6	0.8	0.0	0.0	78.9
1971	28.6	9.4	2.7	5.1	6.8	12.2	1.0	0.3	0.0	0.0	0.0	66.1
1972	26.3	14.1	5.0	4.5	11.8	12.2	0.9	0.5	0.0	7.0	0.0	82.3
1973	30.8	11.4	2.7	7.2	14.9	10.5	1.4	0.0	0.0	12.3	0.0	91.2
1974	8.6	7.3	3.2	8.2	2.8	12.2	2.8	0.0	0.0	0.8	0.0	45.7
1975	5.9	5.9	2.3	6.3	1.9	9.1	4.5	0.5	0.0	1.7	0.0	37.9
1976	10.9	10.4	5.0	7.7	2.7	7.3	2.7	0.0	0.9	3.3	0.0	50.9
1977	55.8	17.7	9.1	15.9	5.4	10.9	15.0	2.7	0.9	13.8	1.0	148.1
1978	21.0	30.0	7.0	15.0	19.0	29.0	32.0	5.0	1.0	1.0	3.0	163.0
1979	40.0	63.0	12.0	16.0	22.0	37.0	46.0	5.0	1.0	2.0	5.0	249.0
1980	27.0	43.0	10.0	12.0	20.0	20.0	35.0	5.0	0.0	3.0	0.0	177.0
1981	20.7	55.6	12.0	27.2	29.7	20.8	40.1	3.1	0.0	0.4	1.4	211.0
1982	21.5	106.3	9.0	74.5	34.2	10.0	18.5	2.0	0.0	0.2	1.7	277.9
1983	11.6	199.7	9.4	11.4	30.4	15.0	16.1	1.9	0.3	1.8	0.8	298.4
1984	32.7	198.0	3.3	13.3	22.8	38.0	23.6	7.7	2.0	0.2	1.4	342.6
1985	106.3	153.1	4.9	17.6	22.9	84.5	34.7	9.0	1.4	0.0	1.7	436.1
1986	135.3	142.7	18.4	24.9	58.7	63.0	45.8	23.7	9.3	0.0	5.3	527.1
1987	109.8	116.7	9.4	18.7	17.8	30.4	30.1	35.0	12.3	12.8	10.7	403.7
1988	185.6	90.3	13.6	25.6	31.4	60.9	29.6	28.0	20.0	0.0	11.6	496.6
1989	228.1	65.8	20.4	12.7	12.5	54.9	19.0	33.0	5.0	0.0	0.8	452.2

Table 11.3. Rockfish sport catch (t)[a] for the Strait of Georgia by statistical area from the creel survey (Shardlow and Collicut 1989a-e).

	Statistical Area[b]									
Year	13	14	15	16	17	18	19	28	29	Creel Total
1982	17.5	10.9	3.2	27.0	18.3	20.9	8.4	25.3	6.1	136.3[c]
1983	26.0	12.5	2.7	29.4	16.4	16.5	26.1	10.4	6.4	146.4
1984	15.9	10.1	3.0	11.3	24.7	14.2	18.7	7.6	5.6	111.1
1985	10.1	8.7	1.2	27.0	14.5	8.5	14.2	5.0	4.6	93.8
1986	14.8	14.5	1.9	34.2	12.9	9.0	20.0	4.9	5.0	117.5
1987	11.5	15.9	2.1	14.4	16.1	10.4	19.5	2.9	2.5	95.4
1988	17.3	21.0	2.0	26.7	21.4	12.0	24.4	4.2	7.4	136.3
1989	13.1	22.3	2.2	33.9	23.6	13.9	20.4	4.2	6.3	139.9

[a] Converted from numbers of fish using an average weight of 0.7 kg.

[b] Areas 12 and 20 are not covered by the creel survey.

[c] Mean of 1980-82 estimates from creel survey.

Table 11.4. Total rockfish line catch (t), rockfish line catch excluding the 'red snapper' catch (QB/CO), total rockfish CPUE (kg/d), quillback/copper (QB/CO) rockfish CPUE, effort (d), and the number of vessels that made a 50-kg qualified catch by geographical area, 1967-89. Effort is calculated from the ratio of total rockfish catch to CPUE.

a) Area 12, Port Hardy

	Catch		CPUE			
Year	Total	QB/CO	Total	QB/CO	Effort	No. of Vess.
1967	9.9		89.4		111	
1968	11.8		34.3		344	
1969	25.3		64.0		395	
1970	23.8		72.3		329	
1971	28.6		65.7		435	
1972	26.3		41.2		638	
1973	30.8		102.4		301	
1974	8.6		36.6		235	
1975	5.9		36.2		163	
1976	10.9		47.5		225	
1977	55.8		80.8		691	
1978	21.0		52.1		403	
1979	40.0		55.0		728	71
1980	27.0		48.7		554	45
1981	20.7		57.3		361	42
1982	21.5		54.9		392	47
1983	11.6	8.4	63.1	52.0	184	37
1984	32.7	17.1	78.9	49.3	415	60
1985	106.5	80.0	70.1	56.6	1519	65
1986	135.3	100.5	86.9	69.1	1556	66
1987	109.8	89.9	71.1	59.6	1545	104
1988	185.6	137.6	74.2	57.0	2501	92
1989	228.1	153.7	71.7	49.6	3181	107

Table 11.4. (cont'd)

b) Area 13, Campbell River

Year	Catch Total	Catch QB/CO	CPUE Total	CPUE QB/CO	Effort	No. of Vess.
1967	7.6		47.8		159	
1968	8.2		60.7		135	
1969	12.0		106.4		113	
1970	16.9		59.6		283	
1971	9.4		61.2		154	
1972	14.1		45.8		308	
1973	11.4		63.7		179	
1974	7.3		52.2		140	
1975	5.9		81.3		73	
1976	10.4		49.8		209	
1977	17.7		51.1		346	
1978	30.0		56.3		533	
1979	63.0		66.9		942	98
1980	43.0		57.7		743	65
1981	55.6		62.8		885	86
1982	106.3		62.2		1709	114
1983	199.7	186.6	51.5	49.5	3876	127
1984	198.0	180.1	47.3	43.7	4186	125
1985	153.1	124.1	46.4	38.1	3302	101
1986	142.7	134.9	44.8	42.5	3184	87
1987	116.7	110.2	45.7	43.6	2554	125
1988	90.3	81.6	56.1	52.3	1610	54
1989	65.8	57.2	46.3	41.4	1453	53

Table 11.4. (cont'd)

c) Areas 15 and 16, Sechelt

	Catch		CPUE			
Year	Total	QB/CO	Total	QB/CO	Effort	No. of Vess.
1967	20.1		56.1		359	
1968	20.0		76.3		262	
1969	20.1		74.7		269	
1970	14.8		47.5		311	
1971	11.9		32.7		364	
1972	16.3		28.2		578	
1973	22.1		67.7		326	
1974	11.0		61.0		180	
1975	8.2		24.7		333	
1976	10.4		39.3		265	
1977	21.3		71.0		300	
1978	34.0		60.1		566	
1979	38.0		84.2		451	162
1980	32.0		65.1		491	117
1981	56.9		104.9		542	88
1982	108.8		79.9		1361	67
1983	41.8	37.0	63.7	64.5	656	71
1984	36.1	35.4	56.1	55.0	644	81
1985	40.5	34.9	84.7	70.8	478	86
1986	83.6	67.9	95.1	87.7	879	97
1987	36.4	13.8	64.1	35.6	568	79
1988	57.0	24.9	59.9	33.1	951	50
1989	25.2	7.9	48.1	21.4	524	37

Table 11.4. (cont'd)

d) Areas 14, 17-19, Gulf Islands

	Catch		CPUE			
Year	Total	QB/CO	Total	QB/CO	Effort	No. of Vess.
1967	14.2		40.7		349	
1968	16.9		31.5		536	
1969	17.1		27.9		613	
1970	22.2		38.0		584	
1971	16.2		58.0		279	
1972	18.6		25.4		733	
1973	14.6		36.8		397	
1974	18.2		28.7		634	
1975	16.4		58.9		278	
1976	15.0		49.3		304	
1977	37.7		55.2		683	
1978	73.0		53.7		1360	
1979	100.0		53.5		1871	65
1980	70.0		50.8		1377	54
1981	76.0		69.5		1093	60
1982	39.5		42.1		938	98
1983	42.4	36.8	42.5	39.4	997	43
1984	72.6	66.5	45.7	43.4	1590	41
1985	133.1	114.2	64.4	57.9	2068	42
1986	150.9	117.9	79.6	66.3	1896	47
1987	104.9	81.1	64.2	58.3	1634	151
1988	132.1	102.8	60.8	50.2	2173	107
1989	127.4	106.1	55.9	47.5	2279	107

Table 11.5. Number of quillback and yelloweye rockfish samples obtained from the commercial fishery with sample size, mean length (mm), and standard error by sex, statistical area and year.

Area	Year	No of Samples	Males			Females			Comb.		
			N	Mean	SE	N	Mean	SE	N	Mean	SE
a) QUILLBACK ROCKFISH (handline gear)											
02	90	1	88	369	3.9	69	383	4.4	157	375	3.0[a]
07	88	1	137	326	3.9	95	317	4.4	232	323	2.9
	89	1	108	329	3.7	72	326	5.2	180	328	3.0
06	90	1	107	365	2.8	55	366	4.4	170	365	2.4
12	84	1	86	391	2.5	139	390	3.7	225	390	2.4
	85	1	140	349	2.5	121	346	2.8	261	348	1.9
	86	2	218	346	4.1	260	374	3.9	479	362	2.8
	87	3	370	351	2.8	392	357	3.1	762	354	2.1
	88	2	212	357	3.9	224	364	3.7	436	361	2.7
	89	2	102	347	4.8	121	356	4.0	571	343	2.0
	90	1	73	348	5.9	89	354	6.2	162	351	4.3
13	84	3	268	325	2.6	297	328	2.7	565	327	1.9
	85	3	609	322	1.9	495	328	2.0	1105	325	1.4
	86	2	294	314	2.9	314	325	3.0	607	319	2.1[b]
	87	2	268	289	2.7	253	291	3.0	521	290	2.0[b]
	88	2	106	327	4.5	105	334	4.3	211	331	3.1[c]
	89	1	-	-	-	-	-	-	118	329	2.7[d]
17	86	2	123	340	4.1	199	353	3.1	323	349	2.5
	89	2	-	-	-	-	-	-	109	331	5.3[d]
18	88	1	139	337	4.8	152	337	5.1	291	337	3.5

[a] Bottom trawl gear

[b] west of Quadra Island (Discovery Passage).

[c] east of Quadra Island.

[d] Data from an on-board observer.

b) YELLOWEYE ROCKFISH (longline gear)

Area	Year	No of Samples	Males			Females			Comb.		
			N	Mean	SE	N	Mean	SE	N	Mean	SE
02	86	1	106	608	6.3	154	591	4.5	260	598	3.7
	89	1	52	640	7.8	54	602	8.3	106	621	6.0
	90	1	45	620	8.2	49	613	7.9	94	616	5.7[a]
	90	1	67	624	6.5	33	597	9.9	100	615	5.6
06	90	1	62	575	9.9	37	553	12.4	100	566	7.7
07	89	1	159	557	5.6	69	541	6.2	228	552	4.4
24	89	1	24	554	11.6	33	559	14.5	57	557	9.6
	90	1	39	568	8.5	24	565	8.2	72	554	6.9
25	88	1	36	539	13.6	63	559	8.5	100	552	7.3
	89	1	25	530	20.8	25	527	16.4	132	539	7.6
27	89	1	40	556	9.1	60	555	8.0	100	560	6.0
16	89	1	42	609	7.3	32	609	7.8	74	609	5.3
17	88	2	110	488	8.0	115	475	6.9	225	481	5.3

[a] Bottom trawl gear

Table 11.6. Approximate 95% confidence intervals for the proportion of the population surviving each year and the corresponding estimates of instantaneous total mortality rate (Z) from quillback and copper rockfish age-frequency data. Samples are identified by the nearest port, sample type (Commercial or Research), statistical area, year(s), and sample size. To enable among-sample comparisons, ages 12 and older were included in all analyses.

Port	Type	Area	N	Year	Survival	Z
Quillback rockfish						
Bella Bella	C	7	223	88	0.93-0.95	0.06
Telegraph Cove	R	12	596	86-87	0.94-0.94	0.06
Telegraph Cove	C	12	207	88	0.93-0.94	0.06
Campbell River	C	13	412	86	0.90-0.92	0.09
Campbell River	R	13	575	86-88	0.86-0.89	0.14
Copper rockfish						
Campbell River	R	13	198	86-88	0.69-0.82	0.28

Table 11.7. Maximum likelihood estimates of von Bertalanffy growth parameters L_∞, k, and t_0 for quillback and copper rockfish length-at-age data collected from three areas. Standard deviations (in parentheses) are determined from the inverse Hessian. Samples are identified by the nearest port, the statistical area, year(s), sex (Male or Female), and sample size. The two Campbell River samples for quillback rockfish represent commercial and research samples, respectively.

Port	Area	Year	Sex	N	L_∞ (mm)	k (yr^{-1})	t_0 (yr)
Quillback Rockfish							
Bella Bella	07	88	M	137	401 (17)	0.046 (0.012)	-13.4 (4.8)
Bella Bella	07	88	F	95	375 (14)	0.073 (0.020)	-6.4 (3.9)
Telegraph Cove	12	86-88	M	409	399 (6)	0.090 (0.009)	-3.9 (1.0)
Telegraph Cove	12	86-88	F	396	419 (7)	0.068 (0.007)	-6.8 (1.3)
Campbell River	13	84,86	M	287	386 (10)	0.085 (0.012)	-6.0 (1.5)
Campbell River	13	84,86	F	314	416 (12)	0.065 (0.010)	-8.1 (1.8)
Campbell River	13	86-88	M	311	410 (17)	0.070 (0.012)	-5.5 (1.5)
Campbell River	13	86-88	F	264	450 (23)	0.054 (0.010)	-6.5 (1.6)
Copper Rockfish							
Campbell River	13	86-88	M	99	318 (8)	0.41 (0.14)	1.5 (1.2)
Campbell River	13	86-88	F	97	394 (48)	0.10 (0.06)	-5.0 (4.0)

Table 11.8. 'Red snapper' (primarily yelloweye rockfish) handline/troll and longline catch (t), CPUE (kg/d) and effort (d) and other rockfish catch (t), CPUE (kg/d) and effort (d) by geographic region. CPUE is based on landings of at least 50 kg. Effort is calculated from the ratio of catch to CPUE. Source: British Columbia catch statistics data files, 1983-1989

	'Red Snapper'			Other Rockfish		
Year	Catch	CPUE	Effort	Catch	CPUE	Effort
A) East Coast Vancouver Island, Statistical Areas 12-20, 28, 29						
1983	26.8	44.0	609	270.9	49.3	5495
1984	46.3	37.9	1222	300.8	44.8	6714
1985	83.2	35.2	2364	354.8	50.2	7068
1986	93.6	57.9	1616	433.3	59.5	7282
1987	91.5	56.5	1619	312.1	53.1	5878
1988	130.9	30.4	4306	365.8	52.2	7008
1989	123.6	30.3	4079	328.6	46.2	7113
B) West Coast Vancouver Island, Statistical Areas 11, 21-27						
1983	33.4	69.5	480	65.9	40.2	1639
1984	66.7	121.2	550	71.0	51.0	1392
1985	111.2	152.4	730	90.2	69.2	1303
1986	362.4	202.3	1791	216.9	111.5	1945
1987	301.2	138.3	2178	293.7	88.9	3304
1988	309.0	206.2	1499	229.0	88.1	2599
1989	440.6	250.8	1757	185.5	88.9	2087
C) Queen Charlotte Islands, Statistical Areas 1-2						
1983	17.6	63.0	279	22.0	40.1	549
1984	26.5	51.7	513	72.1	137.2	526
1985	76.2	136.9	557	74.4	106.6	698
1986	110.6	185.0	598	82.3	131.4	626
1987	105.2	160.2	657	150.9	128.2	1177
1988	189.2	223.1	848	111.5	124.0	899
1989	193.3	175.3	1103	90.4	138.5	653
D) North Coast, Statistical Areas 3-5						
1983	9.0	56.5	159	4.9	23.2	211
1984	19.9	131.7	151	6.2	28.3	219
1985	22.9	75.5	303	16.4	40.4	406
1986	17.2	70.3	245	22.3	70.9	315
1987	45.7	103.2	443	24.9	57.4	434
1988	47.2	105.5	447	16.0	42.4	377
1989	77.2	179.0	432	15.9	48.3	329

Table 11.8. (cont'd)

	'Red Snapper'			Other Rockfish		
Year	Catch	CPUE	Effort	Catch	CPUE	Effort
E) Central Coast, Statistical Areas 6-10						
1983	4.3	45.0	96	10.2	51.4	198
1984	6.9	72.4	95	10.5	40.7	258
1985	14.7	56.0	263	24.6	62.3	395
1986	19.8	74.5	266	42.5	85.9	495
1987	45.7	93.8	488	76.5	77.8	983
1988	69.2	67.1	1031	106.3	76.0	1399
1989	105.1	105.8	993	66.2	57.6	1149

Table 11.9. Total rockfish handline/troll catch (t) by statistical area for the north coast and the west coast of Vancouver Island, from British Columbia catch statistics, Annual Reports, 1956-89. These reports do not distinguish between inshore and offshore statistical areas.

	Statistical Area																	NC	WC
Year	1	2	3	4	5	6	7	8	9	10	11	21	23	24	25	26	27	1-10	11, 21-27
1956	0.0	0.0	0.0	0.0	0.0	0.1	0.3	0.0	0.0	0.0	0.0	0.0	0.1	1.6	0.2	0.0	0.5	0.4	2.4
1957	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2	1.5	0.4	0.7	2.1	0.0	4.9
1958	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.2	1.7	0.8	0.6	1.3	0.1	4.6
1959	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.7	2.8	1.0	0.9	0.7	0.0	6.1
1960	0.0	0.0	0.0	0.1	0.0	0.0	0.5	0.1	0.1	2.4	0.2	0.0	0.5	3.9	1.1	0.5	1.5	3.2	7.7
1961	0.0	0.0	0.0	0.0	0.0	0.0	6.6	0.3	0.2	2.3	0.1	0.0	1.2	1.5	1.1	0.6	2.9	9.4	7.4
1962	0.2	0.0	0.0	0.0	0.0	0.0	6.3	0.5	0.2	3.3	0.7	0.5	2.4	7.5	3.6	1.9	4.6	10.5	21.2
1963	0.1	0.0	0.0	0.0	0.5	0.4	8.2	3.9	1.4	2.9	4.0	0.4	5.2	1.3	4.6	3.5	4.9	17.4	23.0
1964	0.0	0.4	0.0	0.0	0.0	0.0	2.5	0.5	0.3	0.0	0.0	0.1	0.8	0.3	0.2	0.3	3.0	3.7	4.7
1965	0.0	0.0	0.0	0.0	0.1	0.6	0.0	0.9	0.0	0.4	0.4	0.2	1.0	0.8	0.6	0.9	1.5	2.0	5.4
1966	0.0	0.0	0.0	0.0	0.3	0.0	1.0	0.6	0.0	0.8	1.8	0.1	0.7	0.1	0.9	1.2	1.1	2.7	5.9
1967	0.1	0.0	0.0	0.0	0.1	3.8	2.9	0.6	0.1	2.0	0.2	0.0	1.1	1.8	1.6	2.3	0.7	9.6	7.7
1968	0.0	0.0	0.0	0.0	0.0	0.2	0.4	1.9	1.3	0.4	0.1	0.2	0.8	1.0	1.7	0.8	2.7	4.2	7.3
1969	0.0	0.0	0.0	0.0	0.0	0.5	0.9	0.0	1.0	2.1	0.0	1.2	1.5	4.7	3.7	2.0	1.8	4.5	14.9
1970	0.0	0.1	0.6	0.0	6.8	2.7	17.3	2.3	2.0	0.5	0.0	2.3	2.5	7.3	5.4	6.8	7.0	32.3	31.3
1971	0.0	0.1	0.1	0.0	3.4	1.4	6.8	1.3	0.5	0.3	0.8	1.6	5.3	3.8	2.9	2.7	0.7	13.9	17.8
1972	0.0	0.0	0.0	0.0	9.6	4.9	7.5	2.4	0.0	0.7	2.0	1.8	9.7	10.7	9.5	15.6	15.9	25.1	65.2
1973	0.5	2.3	0.2	0.5	0.2	0.2	0.9	0.5	0.5	0.2	0.9	1.4	6.4	6.8	0.5	8.2	4.1	6.0	28.3
1974	0.5	1.1	0.2	0.5	0.5	0.9	0.9	1.4	0.2	0.9	2.3	2.7	13.2	20.9	5.9	11.8	5.9	7.1	62.7
1975	0.9	1.0	0.9	0.2	1.4	0.5	1.8	1.4	0.2	0.2	0.5	4.1	14.1	8.6	1.8	6.4	6.8	8.5	42.3
1976	0.2	1.4	0.5	0.5	0.5	0.9	4.1	1.8	0.5	0.9	1.4	2.7	11.8	8.2	1.8	5.9	6.4	11.3	38.2
1977	0.2	3.6	0.5	0.9	1.4	0.9	3.6	1.4	0.9	0.5	11.3	3.6	16.8	12.7	2.7	5.9	5.9	13.9	58.9
1978	2.0	5.0	0.5	6.0	0.5	1.0	2.0	4.0	1.0	1.0	7.0	1.0	14.0	11.0	3.0	6.0	5.0	23.0	47.0
1979	1.0	5.0	1.0	1.0	0.5	3.0	3.0	1.0	1.0	1.0	8.0	3.0	25.0	20.0	7.0	6.0	9.0	27.5	78.0
1980	4.0	3.0	3.0	4.0	4.0	4.0	4.0	0.5	1.0	1.0	7.0	4.0	18.0	16.0	6.0	7.0	12.0	28.5	70.0
1981	2.4	5.3	0.4	1.2	0.7	1.2	0.9	1.2	0.2	0.7	3.4	1.0	11.8	26.1	5.2	8.4	8.5	14.2	64.4
1982	1.7	5.4	0.4	1.1	0.8	0.2	1.8	0.5	0.9	0.4	5.8	2.7	6.9	14.1	6.8	4.5	11.6	13.2	52.4
1983	3.1	2.0	0.8	4.7	0.3	3.1	0.8	2.3	1.6	1.5	8.5	5.2	17.1	15.3	8.7	7.5	12.3	13.2	66.1
1984	3.8	6.7	6.0	2.6	6.7	3.3	2.2	2.5	0.0	0.2	8.1	0.7	6.5	9.8	1.7	2.7	24.0	34.0	53.5
1985	1.5	4.2	1.3	10.7	1.4	5.4	5.5	0.4	0.1	4.1	12.6	0.2	13.6	11.3	2.6	6.6	27.9	34.6	74.8
1986	3.4	4.6	0.2	7.0	4.3	6.7	7.4	1.3	0.4	1.1	9.2	2.2	31.2	50.8	9.6	10.6	45.6	36.4	159.2
1987	2.9	5.2	1.4	6.1	4.5	8.1	3.6	6.4	0.4	12.3	37.0	5.8	22.4	62.6	37.1	13.1	46.1	50.9	224.1
1988	3.5	3.6	5.7	3.9	22.1	11.9	50.2	5.4	10.1	2.8	24.3	8.5	14.1	27.8	6.8	5.8	19.4	119.2	106.7
1989	16.9	8.4	1.0	13.9	12.5	12.1	16.9	10.1	3.6	10.4	26.3	4.1	9.0	16.1	6.1	7.9	34.8	105.8	104.3

Table 11.10. Rockfish longline catch by statistical area for the north coast and the west coast of Vancouver Island, from British Columbia catch statistics, Annual Reports, 1956-89. These reports do not distinguish between inshore and offshore statistical areas.

	Statistical Area																NC	WC
Year	1	2	3	4	5	6	7	8	9	10	11	21	23	24	25	26	27	1-10	11, 21-27
1956	0.2	1.5	0.0	0.1	0.0	0.6	3.1	0.2	0.3	1.0	0.7	0.1	0.6	1.5	0.0	2.2	18.8	7.0	23.9
1957	1.2	7.9	0.3	0.0	0.0	0.2	3.9	1.4	0.0	0.0	0.0	0.0	2.9	6.8	3.1	3.9	23.4	14.9	40.1
1958	0.1	0.5	0.1	0.0	0.0	0.3	0.6	1.5	0.0	0.0	0.0	0.8	1.0	0.0	6.0	6.8	17.7	3.1	32.3
1959	0.1	0.7	0.0	0.0	0.0	0.1	1.0	1.6	0.2	0.7	0.0	0.0	0.3	2.1	3.0	5.0	25.2	4.4	35.6
1960	1.6	6.9	0.3	1.5	0.1	0.8	0.0	1.5	2.0	0.1	3.0	0.0	0.6	1.2	5.9	5.2	25.7	14.8	41.6
1961	0.8	2.9	0.0	0.0	0.7	1.0	0.3	0.0	0.0	0.6	1.0	0.1	2.2	1.3	5.9	24.4	16.9	6.3	51.8
1962	0.0	13.8	0.0	0.0	0.0	1.6	0.0	0.0	0.0	0.0	1.8	0.4	3.2	2.5	5.6	23.5	21.0	15.4	58.0
1963	0.0	13.2	0.0	1.9	0.4	2.2	3.9	1.2	0.0	0.1	0.1	0.0	2.8	1.4	0.9	13.6	11.2	22.9	30.0
1964	0.0	2.5	0.0	0.2	0.0	0.2	0.0	0.3	0.0	0.8	0.7	1.5	1.1	1.0	0.8	8.6	14.9	4.0	28.6
1965	0.0	10.1	0.1	0.7	0.2	1.4	0.1	0.0	1.0	0.0	0.1	0.6	1.2	0.0	1.6	8.9	9.5	13.6	21.9
1966	2.7	3.7	0.0	0.2	0.0	1.1	3.4	0.3	0.4	0.8	0.0	0.1	1.4	0.0	1.7	14.3	8.4	12.6	25.9
1967	0.9	8.4	0.0	0.8	6.4	0.0	1.1	0.8	0.0	0.0	0.0	0.6	1.0	1.5	4.6	18.9	9.1	18.4	35.7
1968	1.5	1.3	0.0	0.0	0.0	0.0	1.2	2.0	0.0	0.0	0.0	0.1	2.7	0.0	1.4	6.7	17.1	6.0	28.0
1969	0.0	10.5	0.0	0.5	0.0	2.9	15.9	1.0	0.2	3.4	1.8	1.3	1.2	0.5	2.7	19.9	0.8	34.4	28.2
1970	0.0	12.7	0.0	0.2	3.8	24.4	9.3	6.8	0.0	0.4	1.2	0.5	4.2	3.6	0.9	8.2	8.4	57.6	27.0
1971	2.0	25.1	0.0	1.1	5.6	4.3	2.7	9.0	3.1	2.0	1.8	0.0	1.2	0.8	0.0	1.9	2.1	54.9	7.8
1972	0.0	19.0	0.0	2.6	4.9	0.3	7.5	6.4	0.5	0.0	6.0	0.3	1.1	0.0	0.5	8.6	7.2	41.2	23.7
1973	0.0	11.5	2.7	2.7	8.8	8.2	0.2	6.1	0.0	3.4	6.1	0.7	0.7	0.7	0.7	3.4	7.5	43.6	19.8
1974	0.7	36.3	0.7	8.8	11.6	15.0	0.2	4.1	0.0	1.6	3.4	0.0	0.7	0.7	0.0	1.4	4.1	79.0	10.3
1975	3.4	69.4	0.7	8.2	7.5	6.1	8.2	2.0	2.0	4.1	2.7	1.4	1.4	0.0	0.7	0.0	8.8	111.6	15.0
1976	4.1	17.3	0.9	1.8	9.1	5.4	19.5	4.5	0.0	1.4	2.7	2.7	1.8	0.2	0.2	0.2	12.2	64.0	20.0
1977	2.3	29.5	0.5	3.6	7.3	4.5	8.2	5.0	0.2	0.2	23.1	0.2	0.5	0.9	0.5	0.9	15.0	61.3	41.0
1978	3.0	51.0	8.0	14.0	5.0	4.0	11.0	8.0	1.0	0.5	9.0	0.0	1.0	2.0	0.5	1.0	13.0	115.5	26.5
1979	15.0	66.0	2.0	3.0	8.0	6.0	7.0	5.0	1.0	3.0	27.0	1.0	1.0	3.0	3.0	5.0	30.0	116.0	70.0
1980	22.0	61.0	1.0	3.0	4.0	5.0	4.0	3.0	1.0	0.5	20.0	0.5	6.0	0.5	4.0	7.0	22.0	104.5	60.0
1981	17.1	46.4	2.5	3.7	4.7	1.5	1.5	6.2	0.0	0.6	18.1	0.8	1.0	0.5	2.7	4.3	11.1	84.2	38.5
1982	8.2	33.5	2.1	3.7	1.7	5.2	2.6	1.1	0.9	0.3	11.3	0.4	1.1	2.9	0.0	2.0	10.5	59.3	28.2
1983	10.1	26.3	0.6	6.2	1.0	4.2	1.4	1.0	0.0	0.0	9.2	0.5	2.5	0.1	1.4	0.5	23.5	50.8	37.7
1984	8.3	81.6	2.6	12.0	1.0	1.7	2.3	0.6	0.5	2.9	13.8	0.8	6.5	1.3	0.0	0.9	63.3	113.5	86.6
1985	29.5	119.9	6.3	15.2	4.9	9.3	4.9	7.6	0.0	1.6	32.8	3.9	0.0	4.5	5.5	8.7	16.9	199.2	72.3
1986	24.9	159.8	3.7	9.4	14.5	18.2	5.1	19.7	0.1	0.3	55.9	2.0	36.3	56.9	75.6	76.8	116.3	255.7	419.8
1987	55.1	193.5	5.8	12.9	39.9	31.7	19.3	21.6	1.5	17.4	90.8	22.2	30.3	37.8	40.4	37.7	104.0	398.7	363.2
1988	100.0	193.5	9.6	13.4	8.5	37.6	14.6	25.3	0.6	16.9	146.1	6.3	26.3	77.6	36.3	30.5	108.4	420.8	431.5
1989	76.8	181.5	6.1	37.7	21.9	39.3	33.0	20.4	0.1	25.4	165.2	14.0	31.0	69.8	47.5	30.0	164.3	442.2	521.8

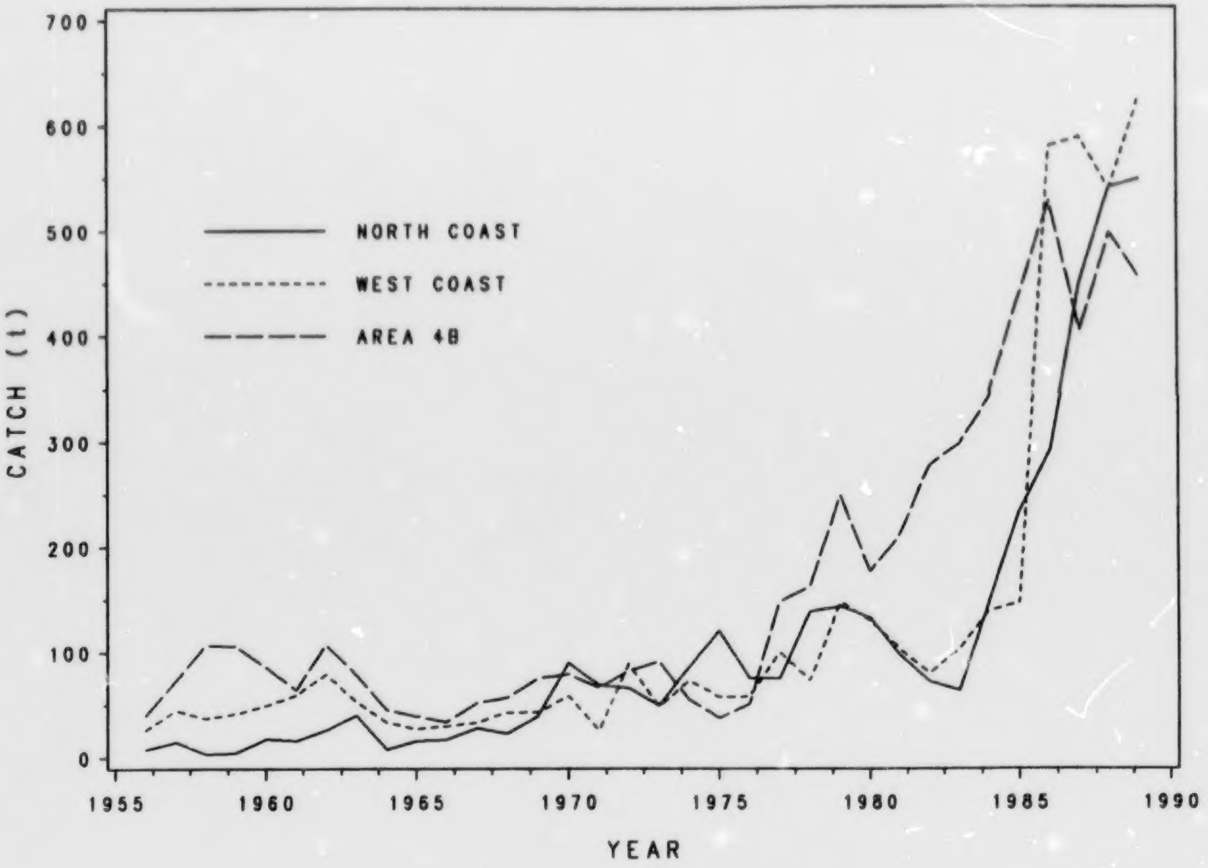

Fig. 11.1. Rockfish handline/troll and longline catch from the Strait of Georgia (areas 12-20, 28, 29), the West coast of Vancouver Island (areas 11, 21-27), and the North coast (areas 1-10).

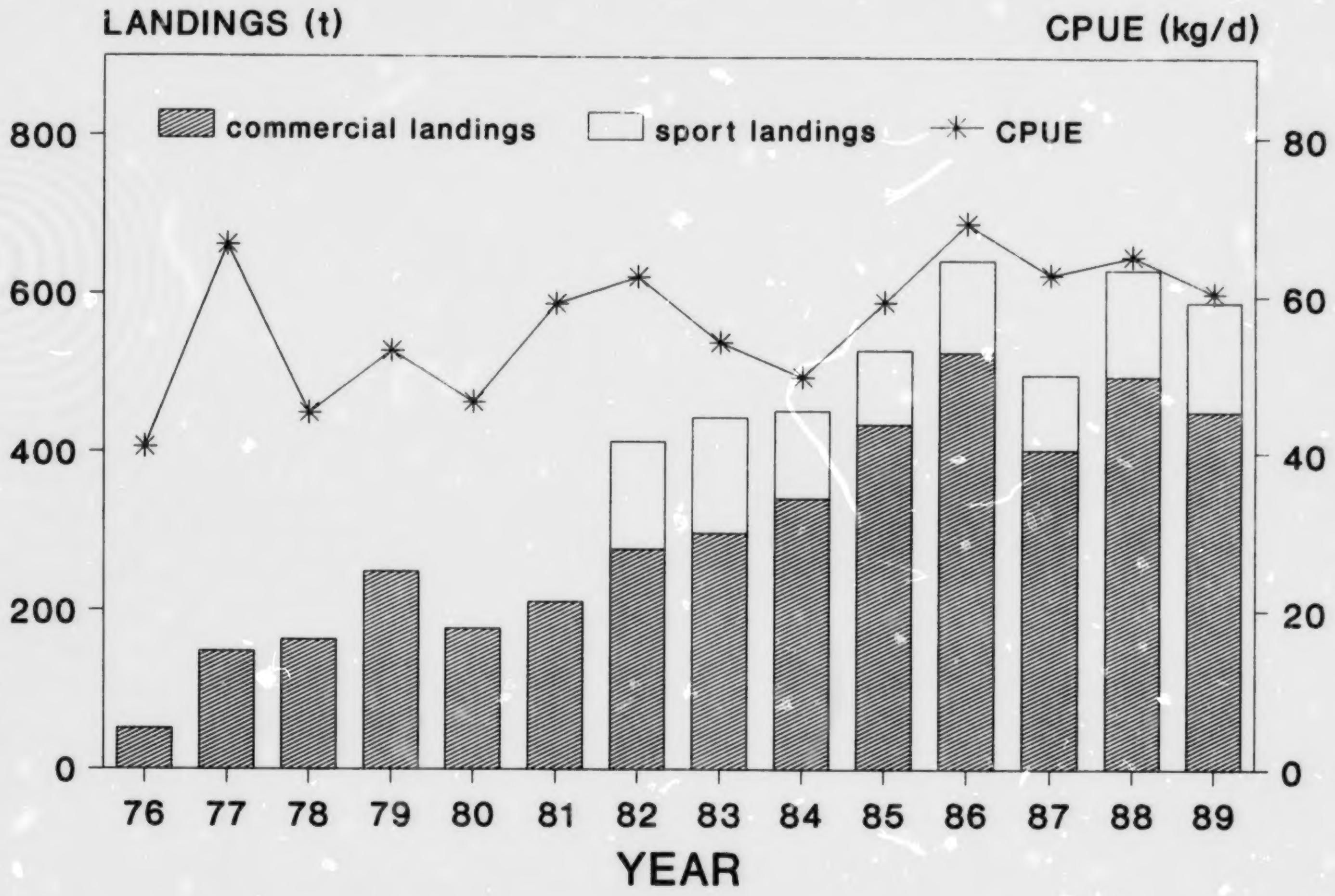

Fig. 11.2. Rockfish commercial handline/troll and longline catch from areas 12-20 and 28-29, sport fishery catch from areas 13-20 and 28-29, and commercial CPUE.

12.0 HAGFISH

12.1 West Coast of Vancouver Island

12.1.1 Introduction

The Pacific hagfish (Eptatretus stouti) is distributed from Baja, California to Alaska. It inhabits a wide depth range (15 to 800 m, 8-400 fa) and is found, predominately, on mud or sand substrate. The fishery for this species is new in B.C. and is classified as experimental. Fishing is or has occurred in management areas 3 - 4, 23 - 27 and 123, with most effort in areas 23 and 123.

12.1.2 Fishery

The number of hagfish permits issued and active during any month since the initiation of the fishery in October of 1988 has ranged from 0 to 11. The fishery is by trap with trap limits per vessel set at 2000 in inside waters and 3500 in offshore waters. The hagfish fishery in British Columbia was initiated due to the demand from the Korean market for a foreign source of "eelskin". In Korea, the fishery for hagfish developed in the mid 1970's and grew to involve a fleet of 1200 vessels. Presently there are fewer than 300 vessels active in Korea, suggesting that stocks may be declining, however, no stock assessment has been done to substantiate this.

12.1.3 Landing Statistics

Landings, effort and CPUE for management areas 23 and 123 have been compiled from October 1988 to June 1990 (tables 12.1 and 12.2, figures 12.1 and 12.2). There have been decreases in CPUE in both areas. In area 23, catch and effort has fluctuated and there have been periods of no fishing (June, August and September). Initial effort in area 23 was high and decreased when areas 24 to 27 were opened to fishing. Effort in area 123 increased to a maximum in September of 1989 and except for November to January has remained relatively constant. This may be attributed to an increase in vessels in June 1989 and an increase in traps in 1990. Total CPUE for area 23 and 123 is similar. No commercial quantities of hagfish were landed in North Coast areas 3 or 4.

12.1.4 General Biological Information

Knowledge of life history and population parameters of the hagfish is sparse. There is little known about age at maturity, growth or migration although it is suggested that hagfish have localized populations (Brodal and Fange 1963). There is nothing known about the frequency of spawning although it is known that only 20 - 30 eggs are released at each spawn. Generally, species with low fecundity are longer lived and are difficult to manage.

12.1.5 Condition of Stock

CPUE has declined in both area 23 and 123. As there is no data on stock separation, it is not known if these declines in CPUE are localized, or if there are any biological factors which may affect the catch rates.

12.1.6 Yield Options

Presently there is no quota for the fishery. Restrictions in place limit the number of vessels, number of traps and areas open to fishing. It is recommended that in 1990 the fishery is retained as an experimental fishery with a condition of the permit being that vessels have biological samples taken monthly by a biological consultant. Also, during any month that fishing occurs, biological samples must be collected from areas 23 and 123. Areas open to fishing may be expanded but control should be maintained on the number of vessels in any area and the permitted number of traps per vessel. Another condition of expansion should be that monthly biological samples from area 23 and 123 continue to be required.

It is not possible to establish longer term management policies for hagfish until more is known about the biology. A research program will have to be developed if this species and the fishery is to be managed to provide sustainable catches.

Table 12.1. Landing statistics for Pacific Hagfish in area 23[a].

Year	Month	Landings (kg)	Effort (traps)	CPUE (month)	CPUE (year)
1988	October	3653.00	4200	0.8698	0.9576
	November	32797.00	28647	1.1449	
	December	29742.00	36275	0.8199	
1989	January	86554.56	104522	0.8281	0.6385
	February	57822.13	81175	0.7123	
	March	12926.15	34000	0.3802	
	April	9763.68	26478	0.3687	
	May	4558.65	12896	0.3535	
	June[b]				
	July	12355.52	21504	0.5746	
	August[b]				
	September[b]				
	October	15085.00	27900	0.5407	
	November	6942.99	13850	0.5013	
	December	20914.63	33077	0.6323	
1990	January	25096.52	52542	0.4776	0.4212
	February	17522.85	39940	0.4387	
	March	18997.00	53422	0.3556	
	April	725.00	2100	0.3452	
	May[b]				
	June[b]				
	Total	28926.7	503406	0.5746	

[a] fisheries branch management area 23 (Barkley Sound).

[b] no fishing.

Table 12.2. Landing statistics for Pacific Hagfish in area 123[a].

Year	Month	Landings (kg)	Effort (traps)	CPUE (month)	CPUE (year)
1988	October[b]				
	November[b]				
	December[b]				
1989	January	2400.00	2505	0.9581	0.6489
	February	12700.00	17368	0.7312	
	March	4550.00	5490	0.8288	
	April	27800.00	26740	1.0396	
	May	48206.00	42232	1.1415	
	June	42875.32	73725	0.5816	
	July	35683.43	46786	0.7627	
	August	57809.96	82651	0.6994	
	September	54461.38	84574	0.6439	
	October	26677.72	42872	0.6222	
	November	9653.91	17544	0.5503	
	December[b]				
1990	January	4932.41	10633	0.4638	0.3012
	February	21404.33	69735	0.3070	
	March	19574.52	49134	0.3984	
	April	10771.56	29518	0.3649	
	May	12441.71	59325	0.2097	
	June	5482.17	29362	0.1867	
	Total	397424.4	690194	0.5758	

[a] fisheries branch management area 123.

[b] no fishing.

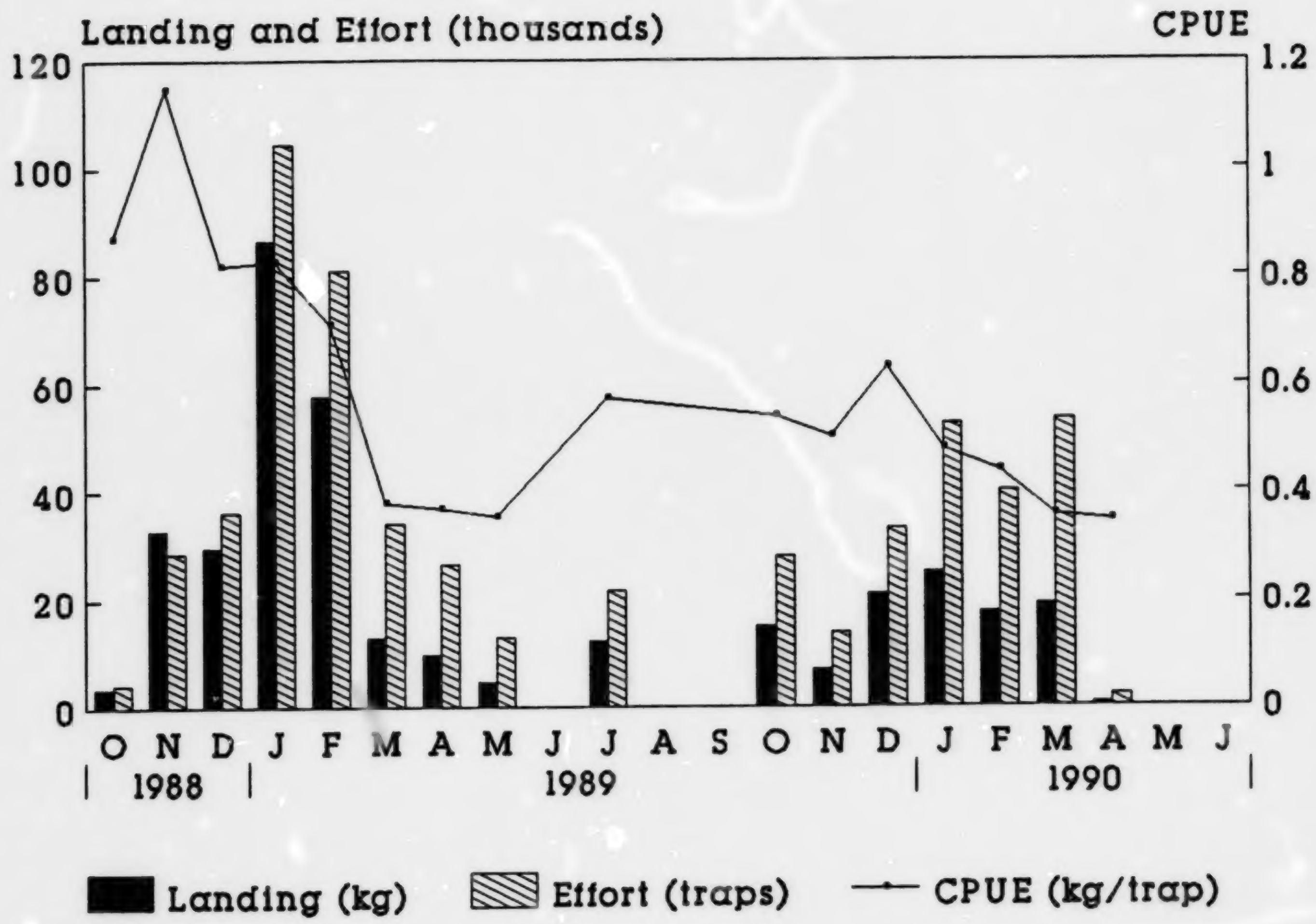

Figure 12.1 Pacific Hagfish landings, effort and CPUE in management area 23.

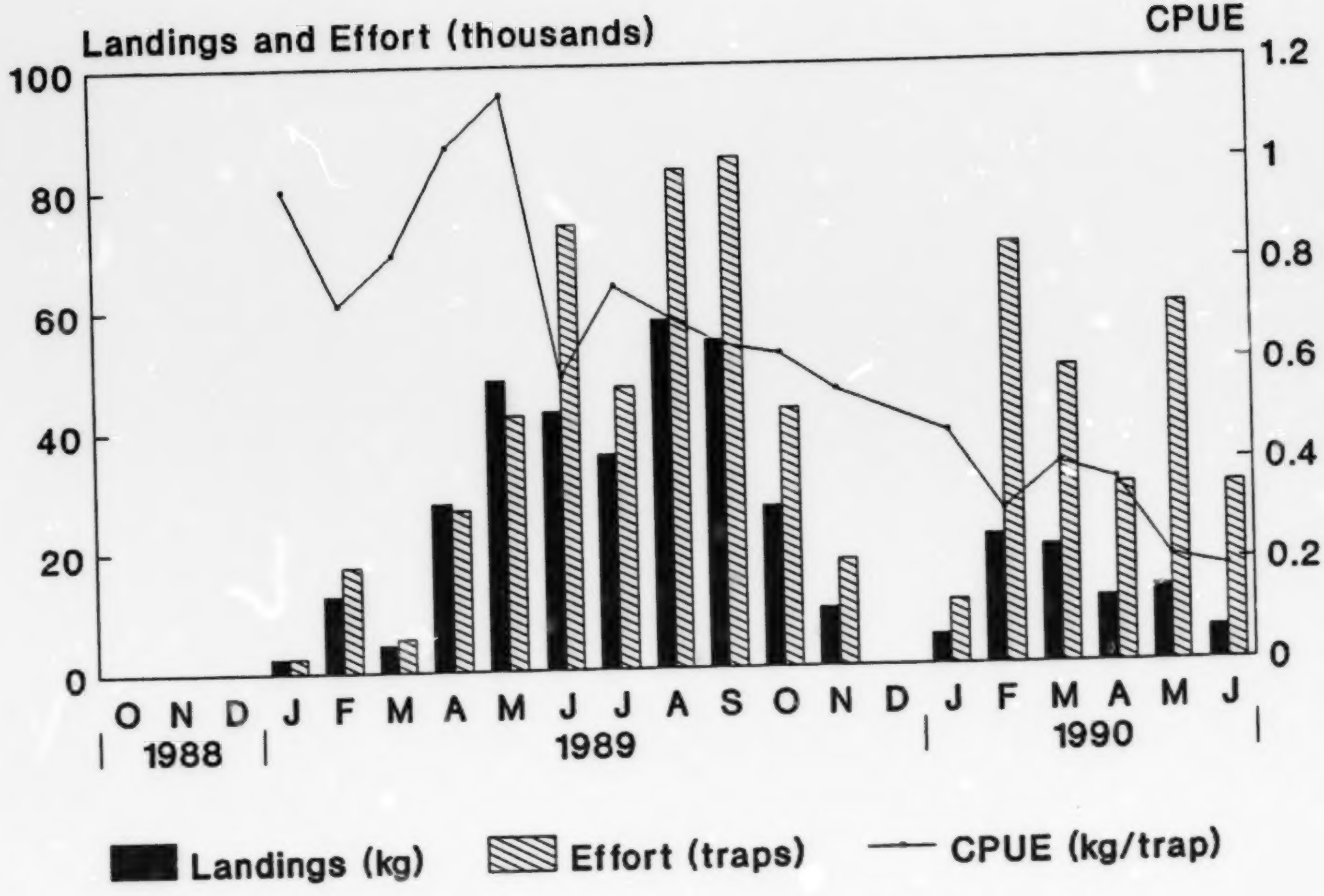

Figure 12.2 Pacific Hagfish landings, effort and CPUE in management area 123.

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